Pollination of Acacia woodlands and honey production by honey bees in Kitui, Kenya

Warui, Mary Wanjiru; Gikungu, Mary ; Bosselmann, Aske Skovmand; Hansted, Lise

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Editorial

Sustainable Agriculture for a Healthy Eco-Systems: Why do we need it?

Prof. Dr. Chandana Rohana Withanachchi is the Dean of Faculty of Social Sciences and Humanities, Rajarata University of Sri Lanka. He is a professor in Archaeology, focusing on the ancient irrigation system. He is a member of the Editorial Board of the Future of Food: Journal on Food, Agriculture and Society.

James Lovelock's Gaia Hypothesis claimed the humans are responsible for exacerbating the conditions on planet Earth and they are killing it. Referring to the production of food, he states that "people everywhere have been amazingly careless about land use and fooled by globalization's cornucopia of food that they seem to think will go on forever" (Lovelock 2009, p. 133). Though the notions presented by the scientists in the camp of "human virus" were highly debated, implicitly we need to accept the truth, that is, the negative human impact on Earth and its future consequences. Since the dawn of civilization and the urban revolution, we have been extremely concerned with urban planning, health, infrastructure facilities, rural development, and so on, however, the accumulation of plastic patches in far Oceans and the decaying green-blue colour of the Earth has become unseen for many. Many of the urban dwellers are no longer able to experience the wonders of the night sky. While we are concerned about counting the human population, every day a statistical record marks a zero in front of another species. So, we invented the terms "pollution" and "extinction" to be worked on and used for creating models. Furthermore, a number of movies are being released, annually, based on the fight or flight to survival in 'dying earth'.

While the issues persist, the human race keeps growing. Changing the face of the earth, or technically the "development", is vital to meet the demands of the growing population. Simple agriculture turned into agribusiness. Then came the 'Green Revolution', followed by the general notion of sustainable development, which are diametrically opposite concepts. Though the Green Revolution showed promising results, yet as soon as it was laid into work, practice showed that it could become the Pandora's Box of which the future generation should deal with. Therefore, the term 'sustainable green revolution' was coined and placed on the table. Though I am not pessimistic about these ventures or the benefits of environmental summits, there will be some lessons we can learn from our ancestors and their knowledge base before going into more technical jargons. However, modern economic development demands more massive visions than those in traditions. Countries should opt either to stay on the traditional paths as Bhutan does or move with the flow without looking at the consequences.

Globally, the current economic structure is going through turbulence. At one point, we started seeing the world as a global market and a universal village. Then it shattered into several regions who grouped into economic landscapes. Europe declared the European Union

(EU), while many other regions have their own bilateral/multilateral agreements under names, such as USA-Canada, Indo-China, The G8 or BIMSTEC. Agreement changes or withdrawals, such as Brexit or the withdrawal of the United Kingdom from the EU, caused change to the image, and the most recent UK expression of interest in investing in the African economy makes it's a more vivid discussion. In this arena, where leading industrialised economies are promoting country first policies, what will be the act of developing nations? Is the producer-market-buyer relationship globally applicable where one country produces, while another country consumes, and a third nation holds the market? Above all what will be the destiny of the economies of the developing countries amidst this scenario? Most simply put, how does a traditional local farmer compete with a multinational agro-company? Notably, the Afro-Asian countries keep alarming a signal. This is of great importance while discussing eco-friendly food production as groups of developing countries report a low carbon footprint. Increasing food production and using chemicals have a direct impact on their eco-systems. Amidst all of these concerns, the wellbeing of the planet earth, it's ecosystems and spheres, and the longevity of human race are becoming more generalised discussions.

This is the point where agriculture and development can help to meet these objectives. Developing countries are at a much higher risk for social and ecological effects than that of developed countries. Evidently, the high-productive and environmental friendly agricultural practices of developing countries were displaced by the green revolution and put the economies into situations that are further complicated. For instance, Sri Lanka had a very self-sufficient agriculture production system, along with its heritage of irrigation (including 30,000+ of man-made tanks), which can be traced back to over two thousand years. However, when the independence of paddy farming first shifted towards large-scale agricultural settlement schemes, the system faced some unexpected failures in terms of land and water demands. The widely used concepts from the green revolution and most of the traditional rice varieties have been declared extinct or nearly extinct, including over 170 of main varieties and accessions of 4,541 rice and related species collected from Sri Lanka as reported by the Plant Genetic Resources Centre (Dassanyake et al., 2013, p. 245). During the late 1970's, the policy priorities shifted from the irredentist movement to an open economy mindset, which expects more socio-economic modernisation. Direct intervention of government on the agricultural market discontinued while the agriculture itself underwent apparent transformations to match with the global market. Structural changes in agriculture marked a new era of labour, finance, land use and technology. Results of these changes are not merely socio-economic but led to more massive crises, ranging from the collapse of old traditions to the stamina of the society. For instance, the chronic kidney disease in North Central province is spreading like an epidemic. As a country with large international debt, the current policy has issues of being autonomous. It is not a surprise that the ban on certain chemicals, including glyphosate, had to lift in front of the internal and external influences. This is familiar in many of the agrarian countries, like Sri Lanka, where making domestic policy decisions has become more arduous, though the severe changes in the agricultural system are required (Vander and Konradsen, 2005, p. 589; Kesavachandran et al., 2009, 33; Wesseling et al., 1997).

During the reign of King Parakramabahu the Great (1153-86), Sri Lanka was considered as the granary of the east. Even at the independence from the British colonial rule, Sri Lanka was once a balanced agricultural and plantation economy, which was capable of feeding the population and exporting some industrial, agricultural products. However, efforts made to increase the plantation exports, rather than fulfilling the domestic requirements, caused issues to emerge that still persist today. With the growing concern for sustainable agriculture and healthy eco-systems, I would like to make a brief note on how the traditional food production was practiced in Sri Lanka regarding the primary basis of paddy cultivation.

Practiced since the early historical period ca. 800BC, the farming system of Sri Lanka, mainly rice and some other home gardening, spread over a wide range of ecological landscapes based on extensive techno-cultural adaptations. The most vital system founded by these early settlers was the irrigation system, which the lifeline of ecosystems and human society was dependent on. This hydraulic civilization were experts in rainwater management, topsoil conservation, pest control, protecting crops from wild animals, among other topics. The system was both autonomous and sustainable. Though some of the methods seemed to be irrational and linked with religious and supernatural beliefs, there are observable results of such methods. As previously mentioned, there were a large number of rice varieties that possess different qualities and attributes. For instance, the Suwandel is rice with fragrant aroma and helps control diabetes. Kalu Heenati is high fibre rice usually used for diabetic patients, pregnant mothers, and as a treatment for snake bite. Kuruluthuda is good for bladder functioning. Madathawalu is for the healthy immune system (IUCN, 2016). Kem, or charm, is a group of traditional methods used for treating humans to cure pests or other effects in

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farming. HCP Bell reports (Bell, 1998), about such a Kem,

> "…When the paddy is about 6 weeks old grubs in turn attack it At this period too, if the rainfall is heavy, the plants are liable to another disease called in Sinhalese ala-kola-rogaya (lit "root and leaf disease"), caused by the rotting of the plants in the water. To avert these mishaps a kema or charm called nava nilla (?nine herbs) is prepared. Getting together nine nili (? green) branches, nine bamboo-canes, each wrapped in nine tender coconut leaves, and an unel plantain leaf, or, failing that, a navari plantain leaf the Kattadiya (charmer) goes at midday to the hena. In the centre of it he fixes the bamboo-canes; then taking two of them, one in each hand, without uttering a sound he plants them in the earth at the exit-stile of the hena. The cultivators have hung beforehand a packet containing untasted kiri-bat at that stile, and watch unobserved….."

This is just a single example from thousands of such practices which are healthy and eco-friendly. All over the world, many agrarian societies do have or had such environmental friendly approaches in farming while affirming the longevity of nature. Currently, Sri Lanka farms more than 95% of the paddy farming on newly modified rice varieties, which should be maintained by regular use of chemicals, non-organic fertiliser and pesticides (IUCN, 2016, p. 9). However, in the present market, increasing demands for organic - traditional rice is observed. This makes for a positive signal.

If we return to the quote we made at the beginning of this article, it is true that the increasing population and changing climatic conditions keep pressuring the earth. Food production is becoming a more vulnerable industry. Furthermore, the solution will be the key abilities of humans to preservere, such as the adaptation and innovation that humans possess which helped them to survive during its evolutionary bottlenecks. Many methods can be learned from traditional farming methods while innovating novel solutions to land scarcity and demand for food, including ways to reduce production costs, enhance soil fertility with sustainable methods, increase profits at the farm household level, and better water management. Developing nations will need to prioritize domestic production to meet the requirements of the country before heading to industrialized economic production techniques. Amalgamation of traditional and industrial concepts will be more fruitful for those who have already reached sufficient levels of agricultural production. The model of Japan provides some good examples, but it will need to allow time for such models to emerge naturally from the people.

The current Volume 6 Issue 1 of the "Future of Food: Journal on Food, Agriculture and Society", on the theme of "Sustainable Agriculture for a Healthy Eco - System" contains papers providing insight to these issues from various regional and global perspectives. Furthermore, this edition is enriched with book reviews that bring a critical outlook of the thematic issues.

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Palm oil supply and demand characteristics and behavior: A system dynamics approach

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Palm oil market, system dynamics, cobweb theorem

Abstract

Like other commodities, palm oil is characterized by common commodity cycles in the market. However, in this study, we argue that the palm oil market has distinctive traits compared to other commodity markets with regard to the cobweb theorem by elaborating on the characteristics of the Malaysian palm oil market and its basic underlying behavior. In an attempt to understand the behavior of the industry, researchers had been changing the paradigm of modelling the palm oil market by using the operationally-based modelling approach (like system dynamics - SD-) rather than the observationally-based modelling approach (like econometrics). Thus, we propose a basic SD model of the palm oil market based on the Malaysian palm oil industry and tested its capability to replicate the real situation in the palm oil market. Five placeholder variables are included in the model to represent the exogenous factors influencing the key variables. Findings from the simulation-based run show that the palm oil market produces a fluctuating pattern of its key variables ceteris paribus, as suggested in cobweb theorem. For future works, further disaggregation of the key variables and exogenous factors is possible, thus adding model complexity in order to achieve specific objectives. This study contributes by setting up the fundamental structure of the market model for palm oil and other similar commodities.

Introduction

Palm oil is one of the most-traded vegetable oils in the global market, along with soybean, rapeseed and sunflower oil. Among its substitutes, palm oil stands out as the most economically-viable vegetable oil in terms of yield per hectare (Tan et al., 2009). Palm oil has been used as an input in various sectors including food and cosmetics as well as being processed into biodiesel to be blended with petro-diesel as an alternative renewable fuel. In the global market, Indonesia and Malaysia contribute the biggest combined production, and account for approximately 86 percent of world production (Malaysian Palm Oil Board (MPOB), 2016; United States Department of Agriculture, 2015). Furthermore, the palm oil industry also contributes to socio-economic development with the aim of alleviating poverty, even though the situation of workers in the sector remains deplorable, particularly their employment status and income (Sinaga, 2013).

A typical commodity market, like palm oil, faces fluctuations in its key variables, like price in particular. As suggested by the cobweb theorem, the causes of price fluctuation in a commodity market are mainly attributed to its supply and demand. In addition, other stochastics exogenous factors also affect key variables and ultimately cause the price to fluctuate (Glöser & Hartwig, 2015).

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The operations research community has been using system dynamics (SD) in modelling commodity markets. In SD, the incorporation of delays and feedback effects of a stock and flow model allows a comprehensive analysis of dynamic market behavior (Sterman, 2000). The generic SD commodity model, proposed by Meadows (1970), has been applied on the livestock market based on the cobweb theorem. The author proposed a dynamic cobweb theorem that installs the dynamics of capacity-building delays of raw materials as the main cause for cyclical price behavior.

Despite sharing common traits with other commodity markets, the palm oil market has distinctive criteria in terms of its supply chain and rule factor of endogenous as well as exogenous variables. For this reason, we attempted to develop a basic palm oil market model based on the generic commodity market model in SD in this study. We also explain the different traits in the palm oil market model compared to other commodity markets. At the end of the study, we developed an SD model representing the fundamental dynamics in the palm oil market. The application of SD in modelling the palm oil industry has helped to highlight the relationship between variables as well as feedback processes in the industry, which sometimes may be overlooked. This holistic view is critical for designing good policies and clearly identifying the important roles played by all elements in the industry (including the people, the market, etc.) in order to achieve sustainability. Moreover, SD demands a high level of community engagement in the modelling process and promotes operational thinking among citizens to design good policies for sustainable agriculture. For this reason, the application of SD accentuates the critical role of citizen science and citizen contribution to the industry dynamic.

To facilitate the understanding of palm oil market behavior, researchers had been changing the paradigm of modelling the palm oil market from using the operationally-based modelling approach (like system dynamics) to the observationally-based modelling approach (like econometrics). This transition can be seen from the studies by Yahaya et al. (2006), Abdulla et al. (2014), Shri-Dewi et al. (2015), and Mohammadi et al. (2016). Operationally-based modelling emphasizes feedback processes following the actual operation happening in a system, rather than the correlational relationships measured by the strength of coefficient values, which is lauded by observationally-based modelling (Olaya, 2015). As such, this study proposes a basic SD model of the palm oil market that is capable of depicting the basic feedback processes and behavior of the palm oil market. The findings of this study contribute to this field by highlighting the characteristics of the palm oil market and its differences compared to other commodity markets, as well as the role played by variables like supply, demand and prices in influencing the behavior of the industry. The goal of this research is to provide a sufficiently good reference for future research in modelling the palm oil market. Furthermore, with some modifications, the proposed model can also serve as a reference in terms of its structure and dynamic behavior for other agricultural commodities, such as cocoa, coconut and rice.

Generic Commodity Market System Dynamics Model

In microeconomic theory, cobweb theorem explains market fluctuations based on the appearance of the supply and demand combinations by showing the shape of a cobweb (Harlow, 1960; Larson 1964; Holt & Craig, 2006). In cobweb theorem, there are three main supply and demand functions with different fluctuations: namely continuous, divergent and convergent (Pashigian, 2008). The supply side exhibits a discontinuous adjustment, while the demand side shows instantaneous reaction to changes in price (Ezekiel, 1938).

Meadows (1970) demonstrated the application of cobweb theorem in a dynamic environment in the livestock market. In dynamic environments, delays in the negative feedbacks controlling inventory, capacity acquisition or other resources are the underlying causes of cyclical movements in many commodity markets. The basic feedback structure of production cycles proposed by Meadows (1970) is illustrated using the Causal Loop Diagram (CLD), shown in Figure 1.

However, commodity markets are also influenced by stochastic exogenous factors like economic crisis, unexpected supply disruptions or other market shocks, which make the market fluctuations less periodical and harder to predict (Gloser & Hartwig, 2015). This is true in the palm oil market, in which supply and demand are influenced by exogenous factor like adverse weather, palm oil tax, soybean prices and even crude oil prices (Shri Dewi et al., 2011; Arshad & Hameed, 2012; Rahman et al., 2013; Abdulla et al., 2014). Thus, in the palm oil market, one can expect a fluctuating pattern perturbed by these exogenous factors, as illustrated by the actual data of the Malaysian palm oil industry in Figure 2.

Most of palm oil market models developed in previous studies were based on the generic commodity cycle model presented with an added degree of detail and some modification based on the model purpose regardless of the industry region. Examples of this are the palm oil SD models in Indonesia (Suryani, 2015) and in Ma-

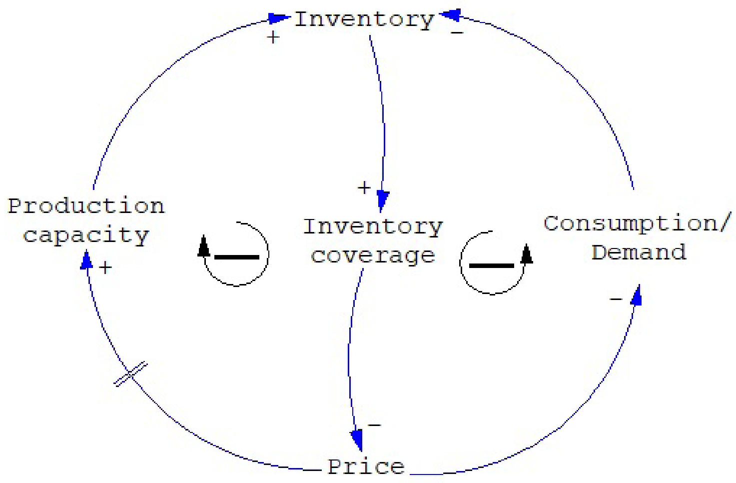

Figure 1: Feedback loop for typical commodity cycles (adapted from Meadows, 1970)

Figure 2: Malaysian palm oil historical data on crude palm oil (CPO) supply, consumption and price (Source: MPOB, 2016)

laysia (Yahaya et al., 2006; Abdulla et al., 2014; Mohammadi, et al. 2015; Shri Dewi et al., 2015). The important question here is how the modeler can effectively model the palm oil industry using SD, while also following the cobweb theorem, considering that the industry itself has its own distinctive characteristics. Thus, this article seeks to answer this question by developing a basic SD model which incorporates the fundamental structure and behavior of the palm oil market (based on the Malaysian palm oil industry, considering its reputation as one of the largest palm oil producers in the world market) involving its supply, demand and price setting mechanism. The model represents the basic dynamics of the palm oil market and can be modified to fit the specific objectives of any modelling project for the palm oil industry in the future.

Malaysian Palm Oil Market Model Characteristics

Before developing the palm oil market model, it is imperative to understand the underlying dynamic behavior in the palm oil market to ensure that the developed model is correct both in structural and behavioral aspects. This section explains the basic characteristics and behavior of the palm oil market based on the Malaysian palm oil industry, as it is the second largest palm oil producer in the world market after Indonesia. This will form a basis for the underlying rules in modelling a generic and robust palm oil market SD model. The developed model, though simple and small in its scope, is assumed to be capable of representing the general behavior of the palm oil market. The basic palm oil market model developed in the next section may be enhanced to include addi-

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tional details depending on the needs of future studies. It is convenient to divide the palm oil market into three main sections: namely production, demand and price setting. Production begins with the oil palm plantations and consists of three phases: namely the immature, mature and ageing phases. Each phase involves different delays which cause uneven patterns in palm oil production. Young seedlings take approximately three years to become mature. In the mature period, oil palm is capable of producing at the maximum yield level for approximately 20 years (Wahid & Simeh, 2010). After 20 years, oil palm has passed its peak production and the yield can decrease by 15 percent (Wahid & Simeh, 2010). Hence, total yield comes from the mature and ageing areas. The oil production process involves the extraction of a certain percentage of extractable oil from the oil palm fruit. The extracted oil is called crude palm oil (CPO) and is recommended for prompt further processing as its Free Fatty Acid (FFA) content will increase if it is stored for a long time, thus deteriorating its quality (Kanagaratnam et al., 2013; Rani et al., 2015).

CPO is distributed for export, local supply for processing to produce processed palm oil (PPO), and as a feedstock for palm-based biodiesel production. The total demand is thus composed of CPO demand from overseas as well as for local processing. Based on microeconomic theory, CPO demand is influenced by its price. However, it is assumed that CPO demand is less sensitive in the short-term due to the fact that most CPO trading is based on long-term future contract prices to reduce the impact from price fluctuation.

Finally, the CPO price setting section, as its name suggests, commands the mechanisms behind setting the price. In a common commodity market, the price setting is largely dictated by the difference between its supply and its demand. Based on microeconomic theory, the price will increase when the demand exceeds supply and vice-versa.

In a generic commodity market model, the long-term expected commodity price determines the expansion of the production capacity (Sterman, 2000). This may be applied when the system contains a short-term capacity expansion capability (for instance, the livestock market in Meadows,1970; or the metal market in Gloser & Hartwig, 2015). For an agricultural commodity like the palm oil market, however, modification has to be made for the link between long-term price and production capacity. In the Malaysian palm oil market in particular, the expansion of oil palm plantation area involves a time delay and several constraints. The time delay includes the delay between planting the seeds and harvesting fruits from mature oil palm trees. Furthermore, oil palm plantation expansion requires suitable land to be converted into plantation area. Malaysia, for instance, is currently facing a scarcity of potential land for oil palm plantation expansion. Although some land is available in the regions of Sabah and Sarawak, it is constrained by issues related to land ownership and suitability (PEMANDU, 2014). Therefore, it is unrealistic to model Malaysian oil palm plantation area expansion based on the long-term CPO prices due to this limitation. Unlike in other commodity markets, oil palm plantations in Malaysia can be assumed to be stagnant, with a very low percentage of expansion or growth.

Another important aspect in considering the linkage between palm oil production capacity and long-term growth is the capability of reducing the production capacity. A typical commodity market may be capable of reducing its production capacity based on the profit derived from its price level (for instance, in the livestock market). However, in the palm oil market, reducing the capacity may not be as swift as in other commodity markets due to the nature of the industry. As an agricultural commodity industry, the production of palm oil requires the supply of oil palm fruits from oil palm plantations. During the low palm oil price period, it is economically infeasible and nonsensical for planters to chop down the trees just to respond to low profit gain. Rather, the planters will continue their business activity, supplying fresh fruit bunches (FFB) and reaping whatever revenue they can while waiting for the price to recover. Planters will behaviorally make profit their utmost priority aside from other uncertainty in the market judging from the amount of input and time they have invested in planting oil palm trees.

This is also true from the perspective of CPO processors. The processors will not stop producing CPO and let the supplied FFB rot unprocessed. In a nutshell, it can be assumed that the price and profit have a low influence on the change in capacity acquisition in the palm oil industry, contrary to other commodity markets. CPO will continue being produced, and therefore market demand is largely responsible for determining the ratio between supply and demand. The main causes for the shrinkage of production capacity is through aggressive measures like closing the plantation area or through the replanting of ageing trees, which creates a time gap of approximately three years of suppressed FFB supply before the young plants becomes mature and therefore capable of producing maximum yield. Hence, it is inappropriate from a behavioral perspective to link profit derived from CPO prices with dynamic change in the plantation area, even in the long term in the context of the Malaysian palm oil industry.

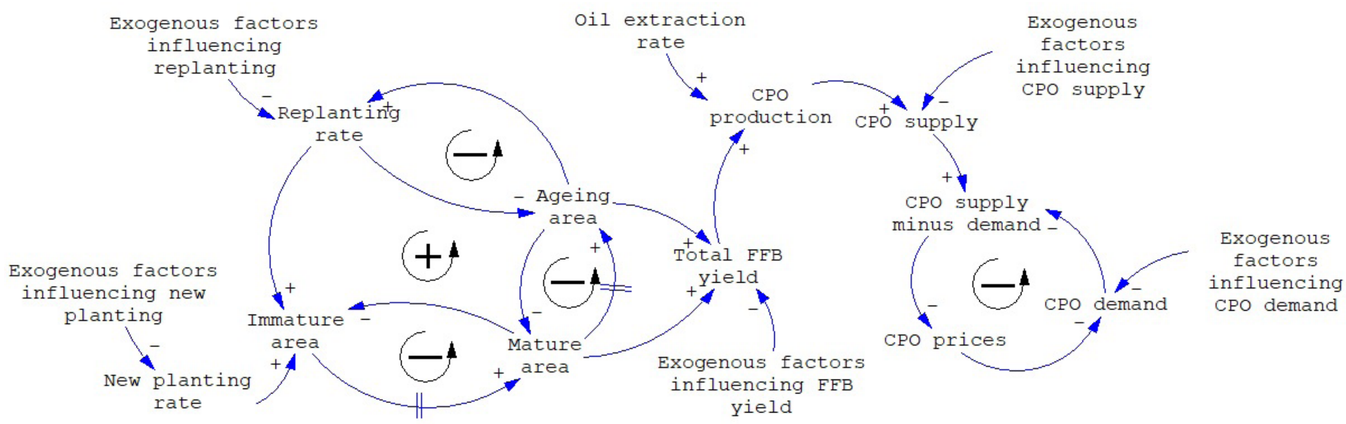

Figure 3: Causal loop diagram of the Malaysian palm oil market. (Authors' Illustration)
CPO = crude palm oil; FFB = fresh fruit bunch

The aforementioned characteristics and underlying dynamics of the palm oil market can be captured using a Causal Loop Diagram (CLD). A CLD is drawn to capture the qualitative model at the beginning of the modelling process. It helps in projecting the cause and effect relationships and feedbacks among variables, particularly for the purpose of capturing the mental model of a problem in a non-technical fashion (Sterman, 2000). Variables are linked by arrows with the appropriate polarity based on their relationship and showing the direction of influence. Positive polarity exhibits a direct influence, while negative polarity exhibits an inverse influence. This helps in forming the feedback processes in the model, which are categorized into positive and negative loops. Positive loops reinforce the variables in the loops, while negative loops balance the output from the loops (Stermand, 2000; Morecroft, 2007).

Figure 3 shows the CLD of the Malaysian palm oil industry, projecting the fundamental interrelationships and feedback processes. It has three negative loops belonging to the plantation sector, whereby each incremental increase in plantation area increases the next area and at the same time reduces the previous area. Collectively, the replanting rate connects the inter-phase process, which closes the plantation sector loop, constituting a positive feedback. Another negative loop is construed by the relationship between CPO supply, demand and prices based on microeconomic theory. This negative loop exhibits the balancing mechanism of the loop. For instance, with excessive supply (high CPO supply minus demand), the CPO price will become low. Low CPO prices will increase demand through more purchase of CPO. However, high purchase of CPO will at some point reduce CPO supply over its demand, thus increasing the CPO prices over time. High CPO prices will then suppress demand and the loop continues. This behavior of the price setting mechanism is expected to produce fluctuations, as suggested by the cobweb theorem.

Malaysian Palm Oil Supply and Demand Model

Despite its usefulness, the CLD only acts as a tool for preliminary analysis of the studied system and can never be taken as a complete imitation of the real system. The limitations of the CLD include the non-distinguishable nature of the variable types and lack of details in the feedback loops of the system (Sterman, 2000). Referring to the CLD in the previous section, we developed a stock and flow diagram (SFD) to capture the basic dynamics in the palm oil supply and demand in Malaysia. Unlike CLD, SFD quantifies the relationship between variables in the form of stocks and flows, thus permitting more detailed analysis of the studied system. Structurally, SFD is much more effective in depicting the real system compared to CLD. The main components that build an SFD are stock, flow, auxiliary and link. Stock refers to the state of the system at a particular time and is also known as the accumulation or level. Flow variables determine the value of the stock, whereby net flow will increase or decrease the value of the stock. Auxiliary is the other variable in the system which specifies the decision rules carrying information between system components. The variables are connected by links in the form of arrows to define the connection and control between the variables in the system.

In this study, the SFD consists of the oil palm plantation sector, the CPO supply and demand section, and the CPO price setting mechanism. In general, the developed model is aggregated to capture the basic palm oil supply and demand dynamics in the Malaysian palm oil industry. There are placeholder variables in the hexagonal box as a suggestion of possible additional exogenous factors influencing the corresponding key variables. These factors could be added with various levels of disaggregation depending on the modelling objective. Via these

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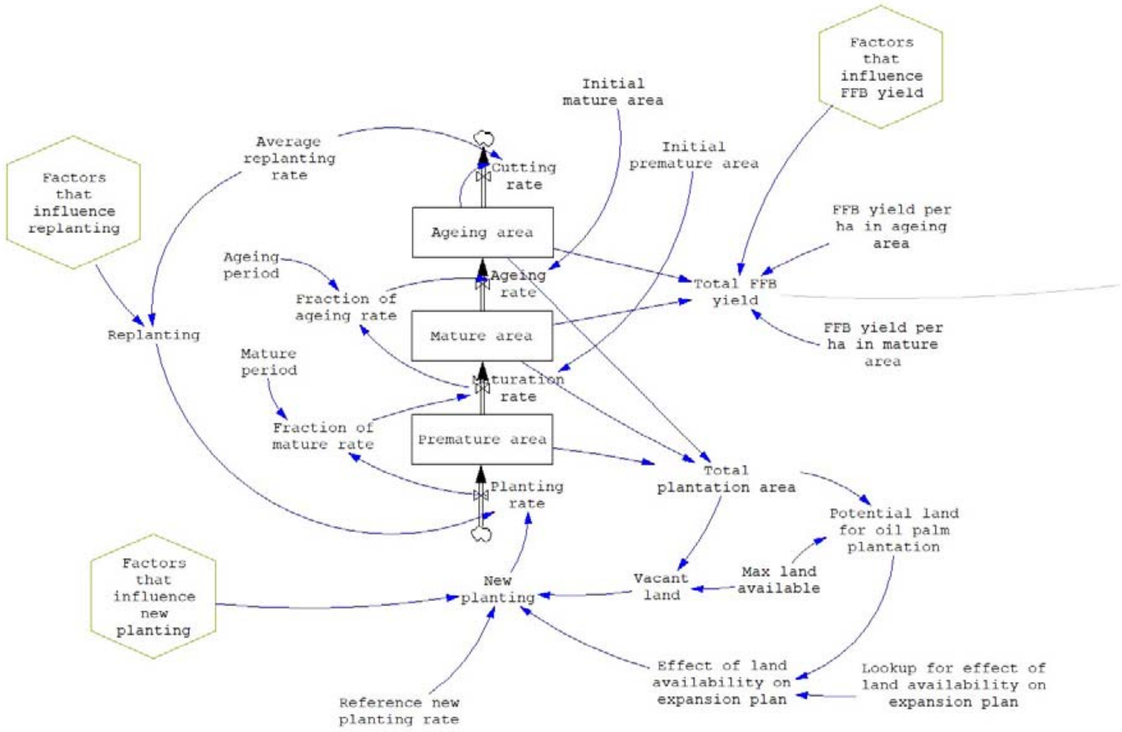

Figure 4: Stock and flow diagram for the oil palm plantation sub-model (Authors' Illustration)

placeholder variables, exogenous factors like substitutes' prices, export taxes and adverse weather can be incorporated into the model as the factors influencing the behavior of key variables (e.g. CPO supply, demand, and prices) in a more logical, operationally-oriented manner. This approach is contrary to observationally-based modelling, whereby the aforementioned factors would be directly related to the key variables and the strength of the correlational relationships would be measured based on the values of the respective coefficients.

The oil palm plantation sector in Figure 4 captures the various phases of the plantation area: namely premature, mature and ageing. The rate of each phase is modelled using a delay to depict the true dynamics of oil palm planting. For instance, 100 hectares of newly planted premature area is expected to become 100 hectares of mature area after 3 years, and 100 hectares of ageing area after 20 years. Equations 1-5 list the key functions in the oil palm plantation sector sub-model. There are three placeholder variables in the model: factors that influence new planting, factors that influence replanting, and factors that influence FFB yield. Equation 1 shows the planting rate, which is composed of new planting and replanting. Equations 2 and 3 are the maturation and ageing rates, which are determined by the fraction of each rate. For the maturation rate, the fraction is calculated based on the planting rate and the delay for the new planted area to become mature, defined by a maturation period as in Equation 4. The ageing rate is calculated in a similar function based on the maturation rate and the delay for the mature area to become ageing, defined by the ageing period as in Equation 5.

Total FFB yield in the oil palm plantation sector sub-model serves as the connection with the CPO price setting sub-model, as shown in Figure 5. CPO production is obtained by multiplying the total FFB yield with the oil extraction rate. CPO demand is aggregated for simplification purposes in this study. The CPO price setting mechanism is based on its supply and demand ratio. In the same loop, CPO price influences the purchase of

$$\textit{Planting rate=New planting+Replanting} \quad (1)$$

$$\textit{Maturation rate=Fraction of mature rate} \quad (2)$$

$$\textit{Ageing rate=Fraction of ageing rate} \quad (3)$$

$$\textit{Fraction of maturation rate=f(Planting rate,Mature period)} \quad (4)$$

$$\textit{Fraction of ageing rate=f(Maturation rate,Ageing period)} \quad (5)$$

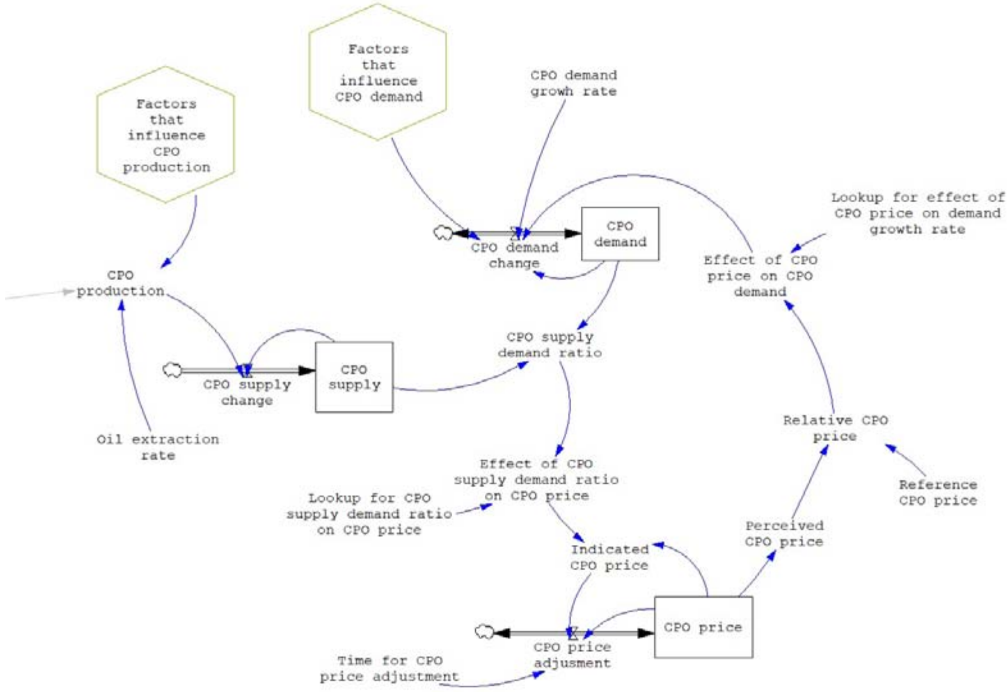

Figure 5: Stock and flow diagram for CPO price setting sub-model (Authors' Illustration)

CPO, thus determining the demand. We modelled the decision to purchase CPO behavior based on a CPO price moving average to represent the non-sensitivity of purchasers to short-term price fluctuations.

Equations 6 to 16 list the key equations in the CPO price setting sub-model. Equation 6 shows the CPO supply formulated in a stock form. The accumulation of the stock is dependent on the CPO supply change (increase or decrease) and the initial CPO supply. The stock form is also used to formulate CPO demand and price in Equation 7 and Equation 8, respectively. The CPO demand stock is accumulated through the demand change and initial demand. In a similar fashion, CPO price stock is accumulated via price adjustment and the initial price. CPO supply change is calculated by multiplying the total FFB yield with the oil extraction rate (the percentage of oil extractable from a tonne of FFB) as in Equation 9. The CPO demand change, on the other hand, is dependent on the demand growth rate, which is also influenced by the effect of CPO price on demand, as in Equation 10. The effect of CPO price on demand is based on the rel-

$$\text{CPO supply}=\int \text{CPO supply change}+\text{CPO supply}_0\,dt \tag{6}$$

$$\text{CPO demand}=\int \text{CPO demand change}+\text{CPOdemand}_0 dt \tag{7}$$

$$\text{CPO price}=\int \text{CPO price adjustment}+\text{CPO price}_0 dt \tag{8}$$

$$\text{CPO supply change}=\text{Total FFB yield}\times\text{Oil extraction rate} \tag{9}$$

$$\text{CPO demand change} = \text{Effect of CPO price on CPO demand}\times\text{CPO demand growth rate} \tag{10}$$

$$\text{Effect of CPO price on CPO demand}=f(\text{Relative CPO price}) \tag{11}$$

$$\text{Relative CPO price}=(\text{Perceived CPO price})/(\text{Reference CPO price}) \tag{12}$$

$$\text{CPO price adjustment}= (\text{Indicated CPO price-CPO price}) / \text{Time for CPO price adjustment}) \tag{13}$$

$$\text{Indicated CPO price}=\text{Effect of CPO supply and demand on CPO price}\times\text{CPO price} \tag{14}$$

$$\text{Effect of CPO supply demand on CPO price}=f\,(\text{Supply demand ratio}) \tag{15}$$

$$\text{CPO supply demand ratio}=(\text{CPO supply })/(\text{ CPO demand}) \tag{16}$$

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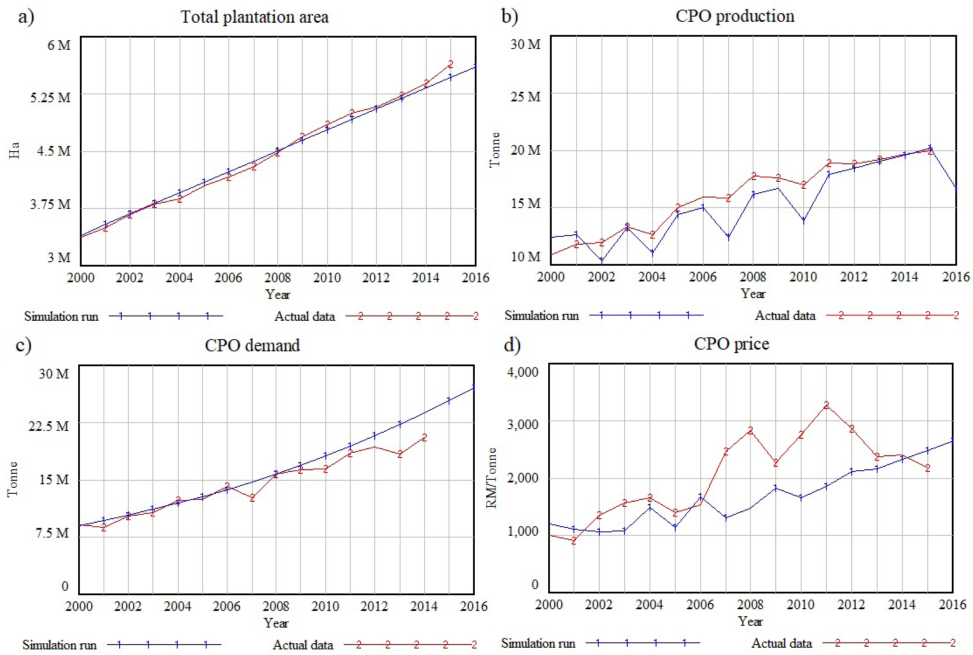

Figure 6: Simulation run comparison with actual data: (a) Total plantation area; (b) crude palm oil (CPO) production; (c) CPO demand; and (d) CPO price. (RM: Malaysian Ringgit)

ative CPO price, as in Equation 11, which is equal to the ratio between perceived CPO price in the market and the reference CPO price, as in Equation 12. In other words, if the perceived CPO price is higher than the reference CPO price (which means the buyers are willing to pay more than the reference price), the ratio will be higher, thus the CPO demand will increase, and vice versa.
The CPO price adjustment in Equation 13 is calculated by dividing the difference between the indicated price and the CPO price with the time needed for the price to be adjusted. This equation incorporates the role of time delay in setting the CPO price in the market. A shorter- term delay means the price is more sensitive to the change, while a longer-term delay means the price is less susceptible to the market sentiment. The indicated CPO price incorporates the effect of CPO supply and demand on the CPO price, as in Equation 14. The effect of CPO supply and demand is based on the supply demand ratio in Equation 15, which is calculated by dividing the CPO supply with CPO demand, as in Equation 16. This equation indicates that as the ratio of CPO supply to demand increases (oversupply), the CPO price will decrease, and vice versa.

In this sub-model, there are two placeholder variables: factors that influence CPO production and factors that influence CPO demand. These placeholder variables can be replaced with exogenous factors (e.g. substitutes' prices, export taxes, adverse weather, etc.) to depict their influences on CPO supply and demand behavior, which leads to the fluctuation in CPO prices. In addition, further details can be added into the model by further disaggregating CPO supply and demand, for instance, by incorporating CPO import and separating CPO demand based on distribution channels such as PPO production, biodiesel production, and exports.

Model Validation and Base Run Simulation

The model has been validated using actual data from the years 2000-2015. Figure 6 shows the comparison of the simulation run and actual data of the key variables, namely the total plantation area, CPO production, CPO demand and CPO price. Statistical error analysis using Root Mean Square Percent Error (RMSPE) and Theil's inequality coefficients has been done for validation purposes (Sterman, 1984). The RMSPE provides a normalized measure of the magnitude of the error. Theil's inequality coefficients on the other hand consist of UM, US, and UC, which reflect the fraction of the mean-square-error due to bias, unequal variance, and unequal covariance, respectively (Sterman, 1984). The results of the statistical error analysis are compiled in Table 1. All variables produced sufficiently small RMSPE values, denoting the close relationship between simulation run data and the actual data. Furthermore, the low Theil's inequality coefficient produced by all variables denotes a satisfying fit of the modelled data to the actual data. A better fit may

Tabel 1: Statistical error analysis of key variables

Variable	RMSPE (%)	Theil's Inequality Coefficients		
		U^M	U^S	U^C
Total plantation area	1.35	0.02	0.57	0.40
CPO production	9.94	0.29	0.00	0.71
CPO demand	9.22	0.40	0.29	0.31
CPO price	27.78	0.38	0.12	0.51

Tabel 2: Parameters used in simulation base run

Variables	Parameter	Unit
Ageing period	20	Years
Average replanting rate	60,000	Hectare/Years
CPO demand growth rate	1	Dimensionless
Factors that influence CPO demand	1	Dimensionless
Factors that influence CPO production	1	Dimensionless
Factors that influence FFB yield	1	Dimensionless
Factors that influence new planting	1	Dimensionless
Factors that influence replanting	1	Dimensionless
FFB yield per ha in ageing area	15	Tonne/Hectare
FFB yield per ha in mature area	22	Tonne/Hectare
Initial ageing area	1,000,000	Hectare
Initial CPO demand	9,000,000	Tonne
Initial CPO price	1,200	Malaysian Ringgit/Tonne
Initial CPO supply	10,800,000	Tonne
Initial mature area	2,000,000	Hectare
Initial premature area	400,000	Hectare
Mature period	3	Years
Oil extraction rate	21	Percent

be obtained with the incorporation of exogenous influence variables represented by the placeholder variables, as shown in SFD in the previous section.

The base run of the model is executed using the parameters shown in Table 2. The parameter values are based on Malaysian palm oil industry data obtained from various sources The running period of the base run simulation was extended until the year 2100 to allow observation of its behavior in the long term. Figure 7 shows the simulation base run for CPO supply, demand and price. As the CPO supply is fairly stagnant, the source of price fluctuation comes from its demand. There is some delay of CPO demand response to CPO price change to depict the low sensitivity of demand change to the CPO price fluctuation. As argued in the previous section, there is no significant influence of the CPO price on the size of the production capacity of Malaysian palm oil due to limita-

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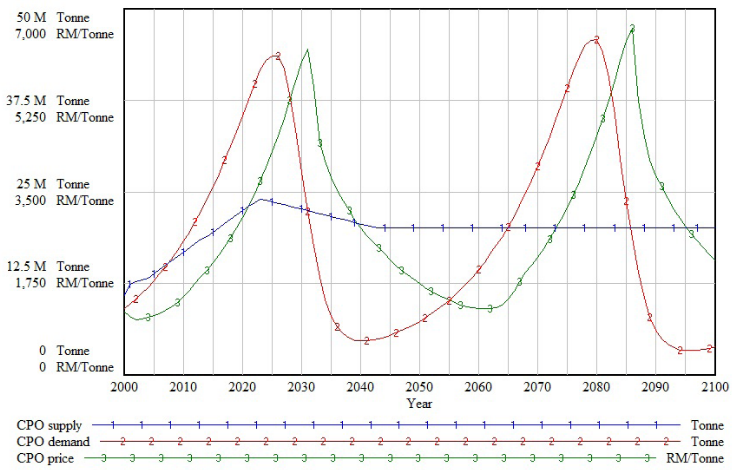

Figure 7: CPO supply, demand and price for simulation base run (RM: Malaysian Ringgit)

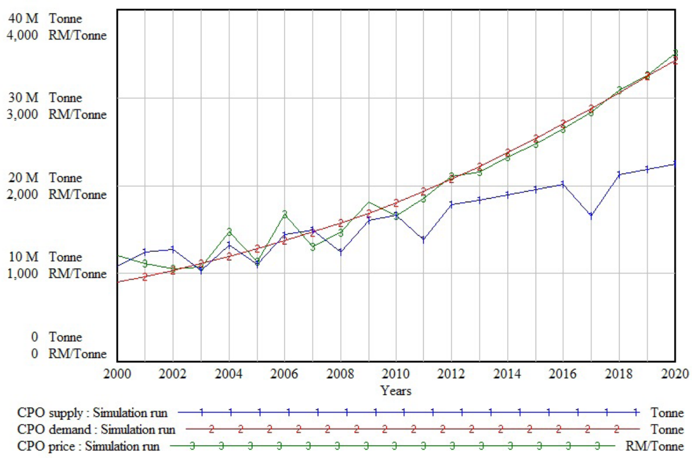

Figure 8: CPO supply, demand, and price with CPO production uncertainty due to exogenous factors (RM: Malaysian Ringgit)

tions to expansion. This explains the relatively constant production in the simulation base run. The fluctuation in CPO price is thus highly attributed to the demand change ceteris paribus.

In the real world, CPO production actually plays an important role in the price setting mechanism, but the source of CPO production fluctuation is largely attributed to exogenous factors (e.g. adverse weather and labor availability). To simulate this, we conducted another simulation in which CPO supply was pre-set with uncertainty elements. As illustrated in Figure 8, uncertain CPO supply is also a huge determinant of CPO price fluctuation ceteris paribus.

This study attempts to develop a basic model of the palm oil market based on the Malaysian context. The obtained simulation base run model of CPO supply, demand and price is based on the assumption that there are no exogenous factors influencing the key variables. In the real world, on the other hand, various exogenous factors may influence key variables, as demonstrated in Figure 8. Thus, in future works, a model expansion may be possible by exploring the effects of exogenous factors. Table 3 compiles a non-exhaustive list of exogenous factors to be considered in the model. The inclusion of these factors may result in more variance in the simulation outcome and dynamic behavior. Nevertheless, the palm oil market model developed in this study has been shown to be capable of representing the basic behavior of Malaysian supply, demand and price for palm oil.

This study attempts to develop a basic model of the palm oil market based on the Malaysian context. The obtained simulation base run model of CPO supply, demand and price is based on the assumption that there are no exogenous factors influencing the key variables. In the real world, on the other hand, various exogenous factors may influence key variables, as demonstrated in Figure 8. Thus, in future works, a model expansion may

Tabel 3: Possible exogenous factors influencing key variables in the palm oil market

Placeholder variables	Possible exogenous factors
Factors that influence CPO demand	Substitutes' prices, crude oil price, taxes and levies
Factors that influence CPO production	Production costs, labor availability
Factors that influence FFB yield	Adverse weather, labor availability
Factors that influence new planting	Seedling price, fertilizer price, labor availability, land area change
Factors that influence replanting	Seedlings price, fertilizer price, government incentives, labor availability, land area change

be possible by exploring the effects of exogenous factors. Table 3 compiles a non-exhaustive list of exogenous factors to be considered in the model. The inclusion of these factors may result in more variance in the simulation outcome and dynamic behavior. Nevertheless, the palm oil market model developed in this study has been shown to be capable of representing the basic behavior of Malaysian supply, demand and price for palm oil.

Conclusions

In this study, an SD model of the palm oil market has been developed to capture the basic underlying dynamic behavior of the Malaysian palm oil industry. Validation of the simulation base run data with actual data has proven the capability of the model to describe the fundamental structure of the Malaysian palm oil industry. The basic model assumed that the oil palm plantation area is currently stagnant based on the current Malaysian palm oil industry situation, which is characterized by limited expansion opportunity. Based on the simulation base run, the palm oil market shows a typical commodity fluctuation pattern, as suggested in the classic cobweb theorem. However, contrary to other commodity markets, the production capacity is stagnant (due to the behavior of producers and planters) and has little response to CPO price (in terms of capacity shrinkage and expansion), but high dependency on exogenous factors. In addition, CPO price has been found to be highly affected by demand ceteris paribus. However, in reality, CPO supply (largely dictated by CPO production) plays an important role in determining CPO prices, even though the base run suggested the capacity is stagnant, because the fluctuation of CPO supply may come from exogenous factors (e.g. adverse weather and labor shortages). To demonstrate this, uncertainty of CPO supply was tested in another simulation run which resulted in fluctuation of CPO prices, indicating CPO supply can play a huge role in determining the prices ceteris paribus.

The findings of this study are expected to contribute to this field by demonstrating the structure and behavior of the palm oil market in terms of the dynamics of its supply, demand and price setting mechanism. For future projects, five placeholder variables representing the exogenous factors influencing the corresponding key variables have been included in the model for further exploration and model expandability. This could include factors that influence CPO demand, CPO production, FFB yield, new planting, and replanting. Any possible exogenous factors could be incorporated via these placeholder variables based on the modelling scope and objectives in the future works. Furthermore, with some modification, the model could also be a good reference for modelling other agricultural commodities like cocoa, coconut and rice.

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Conflict of Interests

The authors hereby declare that there are no conflicts of interests.

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Research Paper

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Assessment of genetic diversity in *Agropyron desertorum* accessions using ISSR molecular marker

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Keywords

Genetic variability, ISSR, *Agropyron desertorum*

Abstract

Molecular markers, such as Inter-Simple Sequence Repeats (ISSR), are relatively easy to use and are highly effective for genetic diversity studies. This research was carried out to evaluate polymorphism and variation among Agropyron accessions. Genetic variability was studied for 13 accessions of *Agropyron desertorum* using molecular markers. Genetic variations for 13 accessions were screened using 15 ISSR primers and 12 primers were scored. The ISSR primers produced 61 bands, of which the polymorphism was observed in 60 bands. The primers IS5, IS11 and IS13 revealed the highest number of bands (7 bands) and IS3 showed the lowest number of bands (3 bands). The highest Polymorphism Information Content (PIC) value (0.44) belonged to IS3, which determined better genetic distance than other primers based on the PIC index. The IS9 with the lowest PIC value (0.27) did not separate the accessions. The average Resolving Power (RP) index was 4.19, of which primers IS5, IS11, IS12 and IS13 had the greatest value of RP. Primers IS3, IS7, and IS14 had the lowest values of RP. However, IS5, IS11 and IS13 had the greatest values, and IS3 and IS15 had the lowest amount of Marker Index (MI) and Effective Multiplex Ratio (EMR). In addition, IS5, IS11 and IS13 could be introduced as desirable primers for the determination of genetic variation based on all indices. The accession of G11 had the highest similarity (0.79) with G10, while the accessions of G4, G5 had the lowest similarity (0.39) with G8. The Agropyron accessions were classified by cluster analysis method based on Dice's coefficient. All of the 13 accessions were grouped into four clusters.

Introduction

Agropyron is one of the most important forage grasses that can be grown in weak and shallow soils, and is cultivated mainly to aid with pasture establishment and reclamation in different climates (Sanderson et al. 2002). The gene pool of Agropyron includes about 19 species in Iran and 150 species worldwide (Bor, 1970). Plant genetic resources are the basis of global food security. They comprise diversity of genetic material contained in traditional varieties, modern cultivars, crop wild relatives, and other wild species in order to improve the rangeland and increase forage production (Arghavani et al., 2010, Farshadfar & Farshadfar, 2008). Since, there is high variation within and among different species of Agropyron, the selection response for improving important traits is high (Arghavani et al., 2010). On the other hand, understanding genetic diversity of certain species is not only useful in addressing questions about evolutionary process and the development of conservation strategies, but also a prerequisite for efficient use of genetic resources in breeding programs. Interest in the genetic structure of natural populations of grass species has increased in the last few years because of the necessity of broadening the knowledge of genetic variations in cultivated species (Che & Li, 2007). Molecular markers provide a

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Tabel 1: List of 13 accessions of *Agropyron desertorum*

accessions	Code	Accessions	Code
G1	4051 – 2066	G8	Alborz 2077(Mix)
G2	3965 – 2059	G9	M – 4036
G3	8848	G10	3477 – 2058
G4	287 – 10	G11	747
G5	plc 1	G12	400
G6	plc 2	G13	3014
G7	341 – 2053		

Tabel 2: Compounds of optimized ISSR reaction

Total volume 20 µl	Compounds of each sample
12.6 µl	ddH2O
2 µl	PCR Buffer (X10)
1.5 µl	MgCl2 (50 mMol)
0.4 µl	Nucleotides mixture (10 mMol)
1.2 µl	Primer (10 µMol)
0.3 µl	Tag polymerase
2 µl	DNA (10 ng)

robust estimate of genetic similarity that was likely not obtained using morphological data alone (Surendhar et al., 2009). Often, the initial objective of DNA profiling of populations is to determine diversity among populations in order to develop genetically distinct subsets of populations in a breeding program or to check for duplicates in a gene bank. In these cases, it may be possible to determine diversity among populations by profiling bulked DNA of the individuals (Rouf Mian et al., 2002). Genetic variations based on DNA markers between and within different species of Agropyron were reported by many researchers (Arghavani et al., 2010; Sun et al., 1999; Sun et al., 2002; Refoufi et al., 2009; Szczepaniak et al., 2009; Dizkirici et al., 2010; Che et al., 2011; Yang et al., 2011). Many PCR-based DNA markers have been developed, including Randomly Amplified Polymorphic DNA (RAPD), Amplified Fragment Length Polymorphism (AFLP), Simple Sequence Repeat (SSR), Expressed Sequence Tag (EST), and Inter-Simple Se¬quence Repeats (ISSR). Among these, RAPD and ISSR are relatively simple to use and are highly effective in plant fingerprinting and phylogenetic studies, which require no prior knowledge of sequence information (Xu et al., 2012; Yousefiazar-Khanian et al., 2016). The first report of inter-simple

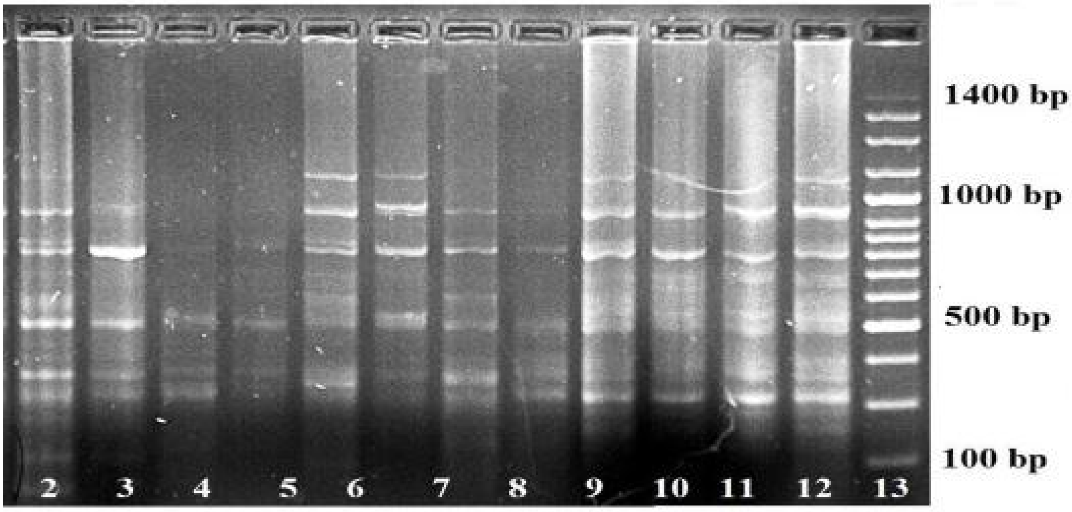

Figure 1: The band pattern for accessions using IS13 primer

sequence repeats (ISSRs) was published in 1994 (Zietkiewicz et al., 1994), which provides genomic information for a range of applications and it is widely used in population genetic studies (Behura, 2006). In other word, ISSR markers have great potential for studying natural populations (Wolfe et al., 1998). Sicard et al. (2005) mentioned that ISSR and RAPD markers were the most widely used compared to the other molecular markers for genetic variation analysis, however, Souframanien and Gopalkrishna (2004) reported that ISSR markers were more effective than RAPD to determine genetic diversity. The objectives of the present research include: (1) determination of the potential of ISSR to generate polymorphic markers in *Agropyron desertorum*; and, (2) identification of the relationship between different Agropyron accessions using ISSR molecular markers.

Materials and methods

Plant Materials: In order to evaluate the genetic variation, 13 accessions of *Agropyron desertorum* were provided from the Natural Resources Gene Bank of Iran at the Research Institute of Forest and Rangeland. (Table 1). The experiment was conducted at the Agriculture and Natural Resources Research center of Kermanshah in Iran.

DNA Extraction and ISSR Method: The total genomic DNA was extracted from young leaves of greenhouse-grown plants using a modified CTAB (Murry & Tompson, 1980) with modification described by De la Rosa et al. (2002). The quality and quantity of extracted DNA were examined using 0.8% agarose gel. The PCR mixtures were carried out according to Table 2. Template DNA was initially denatured at 92ºC for 5 minutes, followed by 35 cycles of PCR amplification under the following parameters: denaturation for 30 seconds at 95º C, primer annealing for 30 seconds at the temperature based on primer temperature (50, 55 and 60º C), and final extension for 1 minute at 72º C. A final incubation was performed for 5 minutes at 72º C to ensure that the primer extension reaction proceeded to completion. The PCR amplified products were separated by electrophoresis with 1.5% agarose gels and a TBE buffer. The gels were placed in the ethidium bromide for 30-45 minutes and visualized using gel documentation. ISSR bands were treated as binary characters and coded accordingly (presence =1, absence = 0).

Statistical Analysis: The Number of Scored Bands (NSB), the Number of Polymorphic Bands (NPB), the Percentage of Polymorphism Bands (PPB), and the Polymorphism Information Content ($PIC = 1 - \sum_{i=1}^{n} PI^2$)were calculated for each primer (Anderson et al., 1993), in addition to the Marker Index (MI= PIC × E) (Powell et al., 1996), Effective Multiplex Ratio (EMR= NPB × β) (Kumar et al., 2009), and Resolving Power (RP=∑IB) (Altıntas et al., 2008). Matrix similarity was computed based on Dice's coefficient NTSYSpc 2.02e (Rohlf & Taxonomy, 1998), and the cluster analysis was performed for grouping accessions based on Dice's coefficient according to the UPGMA method. Principal coordinate analysis was performed to better interpret the genetic variation between accessions DARwin 6 (Perrier & Jacquemoud-Collet, 2006), and finally, the analysis of molecular variance GenAlEx 6.2 (Peakall & Smouse, 2006) was performed for the three groups using cluster analysis.

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Tabel 3: Polymorphism percentage, total bands, PIC, MI, EMR, RP of ISSR markers

Primer code		No. of polymorphism induced (proliferated)	No. of polymorphism place	Polymorphism Percentage	PIC	MI	EMR	RP
IS3	5' GAGAGAGAGAGAGAGAYC 3'	3	3	100	0.44	1.33	3.00	2.15
IS10	5' GAGAGAGAGAGAGAGARC 3'	5	5	100	0.34	1.68	5.00	5.38
IS6	5'-CACACACACACACACAG -3'	5	5	100	0.41	2.04	5.00	3.08
IS7	5'DBDACACACACACACACA3'	4	4	100	0.43	1.70	4.00	2.77
IS13	5' AGAGAGAGAGAGAGAGYT 3'	7	6	85.71	0.32	2.39	5.14	6.46
IS5	5' AGAGAGAGAGAGAGAGC 3'	7	7	100	0.43	3.01	7.00	6.77
IS11	5' ACACACACACACACACC 3'	7	7	100	0.37	2.60	7.00	7.38
IS12	5' TGTGTGTGTGTGTGTGG 3'	5	5	100	0.37	1.87	5.00	6.92
IS9	5' CTCTCTCTCTCTCTCTG 3'	5	5	100	0.27	1.35	5.00	6.15
IS14	5' GACAGACAGACAGACA 3'	4	4	100	0.40	1.59	4.00	2.31
IS15	5' GGATGGATGGATGGAT 3'	4	4	100	0.33	1.30	4.00	5.38
IS16	5'DBDACACACACACACACA3'	5	5	100	0.41	2.06	5.00	4.15
		5.08	5.00	96.73	0.38	1.91	4.93	4.91

Results

ISSR Polymorphism: Primers, sequences, code, number of bands scored, number of polymorphic bands, percent of PPB and Polymorphism Information Content (PIC), Marker Index (MI), Effective Multiplex Ratio (EMR), Resolving power (RP) were showed for 12 ISSR primers in Table 3. For all primers, the numbers of 61 bands were scored but only 60 polymorphisms were observed. The IS5, IS11, IS13 primers had the highest number of bands with 7 bands, and primer IS3 with 3 bands had the lowest number of bands. Band pattern of accessions for IS13 was showed in Figure 1. The lowest percentage of polymorphism belonged to IS13 (85.71%) and the highest percentage of polymorphism was 100% for other primers. The average value of polymorphism percentage was 96.73. The mean value of PIC for all primers was 0.38, and the highest value of PIC belonged to IS3 (0.44), while the lowest value (0.33) belonged to IS15 primers. The mean amount of MI was 1.91, and the largest MI was IS5 with 3.01, and the lowest value was IS15 with 1.30. The average EMR was 4.93, and the IS5 and IS11 were 7. The average of RP was 4.91, and the largest value was IS11 with 7.38, though, the lowest was IS3 with 2.15.

Similarity Matrix: Similarity matrix based on Dice's coefficient for accessions varied between 0.39 and 0.79 (Table 4). The greatest value of similarity was observed between accessions G11 and G10 with 0.79, while the least value was G5, G4 with G8 (0.39).

The frequency distribution histogram showed that the number of accessions with about 0.41 distance was the greatest amount and accessions with about 0.65 distance were the least amount of frequency indicate that the number of accessions with moderate distance were higher than the others (Figure 2).

Cluster Analysis: Based on Dice's coefficient (Figure 3), the UPGMA hierarchical clustering for grouping accessions were identified for the four distinctive groups. The first group consisted of accessions G3, G4, and G5 with mean similarity 0.61. The second cluster included G1, G2, G6, and G7 with a 0.71 value of similarity. The third group

Tabel 4: Similarity matrix between Agropyron accessions based on ISSR primers

	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10	G11	G12	G13
G1	1.00												
G2	0.76	1.00											
G3	0.68	0.73	1.00										
G4	0.48	0.56	0.59	1.00									
G5	0.46	0.50	0.69	0.56	1.00								
G6	0.67	0.72	0.56	0.66	0.53	1.00							
G7	0.68	0.74	0.62	0.51	0.48	0.75	1.00						
G8	0.63	0.55	0.52	0.39	0.39	0.48	0.57	1.00					
G9	0.56	0.63	0.63	0.48	0.61	0.59	0.58	0.55	1.00				
G10	0.69	0.61	0.61	0.57	0.54	0.57	0.63	0.52	0.58	1.00			
G11	0.63	0.52	0.61	0.50	0.55	0.58	0.60	0.56	0.48	0.79	1.00		
G12	0.55	0.53	0.62	0.62	0.56	0.58	0.55	0.60	0.59	0.67	0.73	1.00	
G13	0.66	0.61	0.64	0.42	0.50	0.54	0.63	0.59	0.64	0.62	0.59	0.67	1.00

consisted of G10, G11, and G12 with 0.72 similarities. The forth cluster included G8, G9, and G13 with a 0.59 similarity coefficient. Similarity between clusters was showed in Table 4. Maximum similarity was between cluster 1 and cluster 4, while the least similarity was between cluster 2 and cluster 3.

Principal Coordinate Analysis (PCo): Scatter plot for accessions based on first (26.01) and the second (20.20) axis from principal coordinate analysis (Figure 4) showed that genetic variation did not match with the geographical distribution of accessions. These results, confirmed by cluster analysis and similarity matrix, grouped the accessions into four clusters.

Molecular Variance Analysis: Analysis of Molecular Variance (AMOVA) was performed for ISSR bands to determine significant differences between groups of accessions based on cluster analysis (Table 6). The results showed a statistically significant difference ($p<0.01$) between groups and the portion of variance percentage for the variables between group and within group were 23% and 77%, respectively. Results indicated that the portion of variance within groups with 77% was much greater than among groups with 23%.

Discussion

This research revealed that the genetic pattern of Agropyron accession can be determined using ISSR in the short-term. The results proved that ISSR markers are suitable for detecting the genetic variation in Agropyron accessions. The average of PPB in the present investigation indicated a high polymorphism among Agropyron accessions based on ISSR primers. Ma et al. (2008) reported the percentage of (PPB)=77.20% for accessions of Elymous sibiricus and mentioned that, according to ISSR markers, there was a high level of variation between accessions. Moreover, all primers used in the study were helpful for determination of genetic diversity based on PPB in Agropyron populations, however measurements, such as PIC, and the primers IS3, IS6, IS7, IS5, IS14, and IS16 were useful for polymorphism study and can be used in further analysis of genome for other Agropyron accessions in future research. Efficiency of ISSR primers were reported by other researchers to determine the

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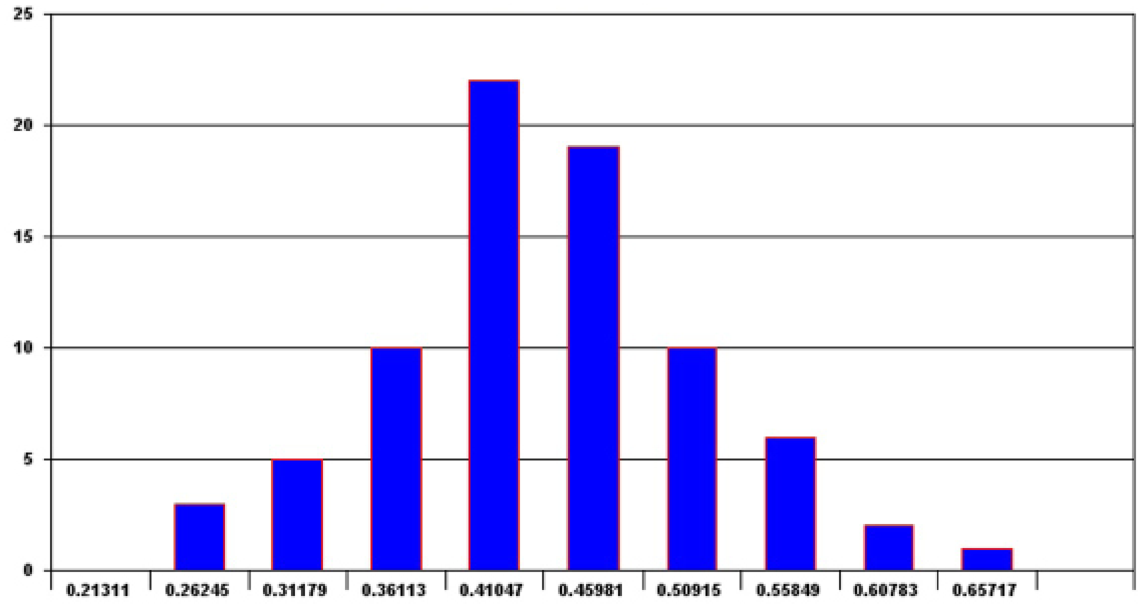

Figure 2: Amount of distance estimated between *Agropyron accessions*

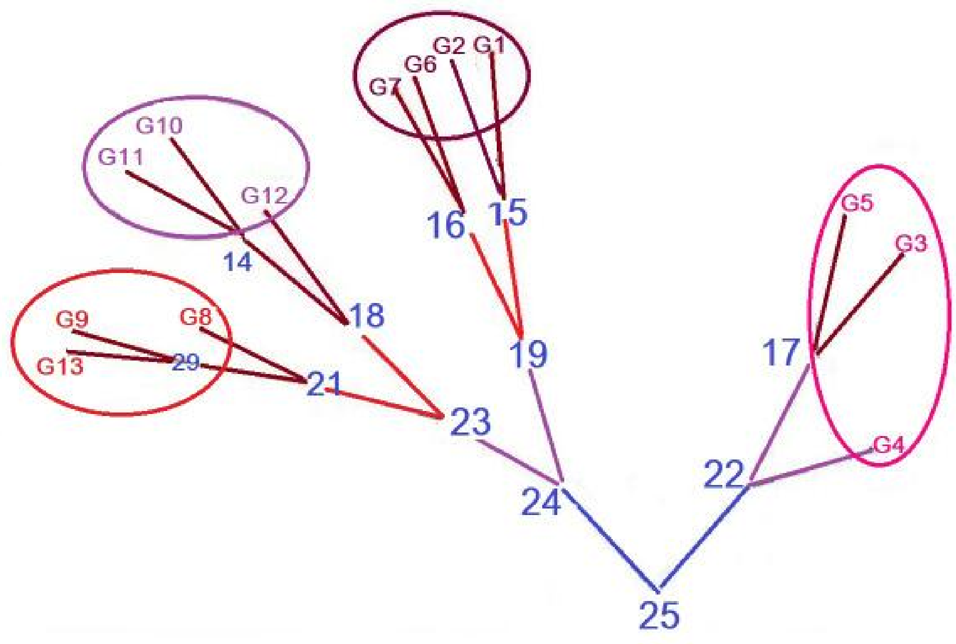

Figure 3: Dendrogram of *Agropyron* accession based on ISSR primers

genetic diversity between and within different plant species (Pivoriene & Pasakinskiene, 2008; Hu et al., 2011; Fasih et al., 2013; Shirvani et al., 2013; Shirvani et al., 2014). Based on Dice's coefficient, the similarity between accessions was low, therefore it can be stated that there was high genetic variation among accessions. In general, according to all indices, the primers IS5, IS11, and IS13 were the best ones to identify genetic variation among Agropyron. Esnault and Refoufi (2008), by using RAPD and isozymes, measured the genetic variation among Agropyron species with different ploidy levels. Grouping of accessions, based on cluster analysis and principal coordinate analysis, indicated that genetic variations are not in accordance with the geographical distribution of accessions. There are several possible explanations for these results, such that some of them are connected through nature, and also that the structure of different molecular markers are designed from various regions of genome, among other reasons. An additional problem was the possibility of overestimating genetic similarity

Table 5: Similarity coefficient between cluster

Clusters	Cluster1	Cluster2	Cluster3	Cluster4
Cluster1	1.000			
Cluster2	0.790	1.000		
Cluster3	0.820	0.768	1.000	
Cluster4	0.837	0.811	0.791	1.000

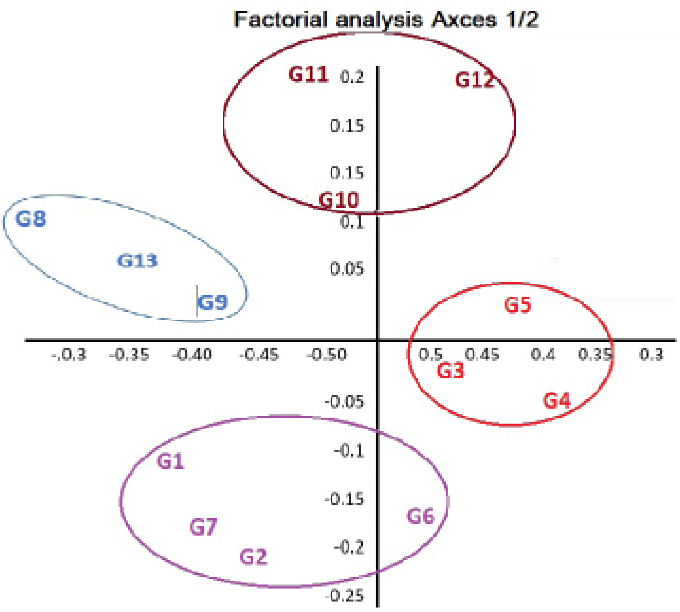

Figure 5: Distribution diagram of accessions in regard to the first and second PCo

Table 6: Analysis of molecular of variance based on ISSR markers

S.O.V	Df	SS	MS	Est. Var.	Var%	PhiPT
Between group	3	59.423	19.808	3.053	23%	0.235*
Within group	9	89.500	9.944	9.944	77%	
Total	12	148.923		12.997	100%	

as the fragments with the same size could have different origins (Suvendu et al., 2009; Poczai et al., 2013; Etminan et al., 2016). The results from the cluster analysis were confirmed by AMOVA. On the other hand, the results of estimated variance indicating the genetic variation the within group variable was more than the between group variable, and can be explained by the high genetic variation between accessions (Etminan et al., 2018; Moradkhani et al., 2015). Finally, based on ISSR markers, the accessions of the first group (G3, G4, G5) had higher

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genetic distance compared to the accessions of the forth group (G8, G9, G13). As depicted by the high diversity between these two groups, they would be appropriate partners in crossing programs to obtain high yield and heterosis.

Conclusions

The assessment of genetic diversity is important, not only for crop improvement, but also for efficient management and conservation of germplasm resources. The current study confirmed the importance of molecular studies data in detecting genetic variation among genotypes to select diverse parents in order to carry out a new crossing program successfully. We believe that there is a need for molecular marker studies as a complementary study to the morphological traits in the field. The primers IS3, IS6, IS7, IS5, IS14, and IS16 were useful for polymorphism study and can be used for the analysis of genome and other Agropyron accessions in future research. The grouping of accessions based on cluster analysis and principal coordinate analysis indicated that genetic variations are not in accordance with the geographical distribution of accessions. The greatest value of similarity was observed between accessions G11 and G10 with 0.79, while the least value was G5, G4 and G8 with 0.39. Due to the high diversity between these two groups, they would be considered appropriate partners in crossing programs to obtain high yield and heterosis.

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Conflict of Interests

The authors hereby declare that there is no conflict of interests.

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Research Paper

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Vertical price linkages in food markets: Evidence from the tomato value chain of Northern South Africa

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Keywords

Marketing margins, Price transmission, Tomato value chain, Vertical price linkages

Abstract

Price transmission in agricultural fresh produce markets is a subject of considerable interest to policymakers given that improved market performance for agricultural commodities promotes market development and maximization of social welfare. In northern South Africa, where tomato production dominates the country, studies exist on the general production, marketing, and consumption of fresh produce. However, the literature lacks an analytical component that is pertinent to the mechanism of price transmission and vertical linkages among successive marketing stages of tomato. This study employs the Houck approach and Error Correction modeling technique in an attempt to examine price transmission in South Africa's tomato markets. The results indicate a symmetric adjustment to price signals between farm and wholesale levels and an asymmetric adjustment between farm and retail levels. Even so, there is scope for ameliorating the effectiveness and efficiency of fresh produce markets in South Africa.

Introduction and background

The food market has generally experienced sustained rising consumer prices and it would interest agricultural economists and policy engineers to know whether farm gate prices are moving in the same fashion with the evident consumer price increases. With respect to tomato marketing in northern South Africa, it is apparent that consumers are increasingly vulnerable to continual price inflation of this agricultural commodity. However, it is uncertain whether the farmers' proportion of the consumer's Rand is symmetrical to these downstream price movements. The objective of this research paper is to answer whether intermediaries in the tomato value chain of northern South Africa are passing more rapidly cost increases while transmitting slowly and less completely cost savings.

As demonstrated by Vavra and Goodwin (2005), the impact of any impending positive or negative price shocks on value chain participants depends on several factors, such as the degree to which market players adjust to price signals, their response time, and the extent to which their adjustments to price shocks are asymmetric. This paper aims to analyze the tomato value chain of northern South Africa by employing the Houck approach and Error Correction modeling techniques, in an attempt to uncover these price transmission uncertainties amongst the three marketing levels: farm gate, wholesale and retail.

In South Africa, Alemu and Ogundeji (2010) report that efforts by the Department of Agriculture, Forestry and Fisheries, formerly known as the National Department of Agriculture, to bring stakeholders forward to explore the cause of rising food prices resulted in a deadlock as it could not be established where the problem of rising food prices emanated. Producers argued that they benefitted little from increased food prices and were under pressure from the cost price squeeze, whereas processors and retailers indicated that increasing prices were necessitated by the high costs of providing value addition in food markets.

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According to Louw *et al*. (2006), the market changes in the agricultural sector of South Africa since the end of apartheid have brought about market concentration in the agro-food sector, as dominant market players tend to favour suppliers who can ensure and sustain high volumes and consistent quality. In the case of tomato, Sautier *et al*. (2006) indicate that only four tomato producers account for about 80% of the total tomato volume in the whole country. The Department of Agriculture, Forestry and Fisheries (DAFF) of the Republic of South Africa (2014) also confirms the presence of high market concentration in the tomato industry where the commercial sector contributes about 95% of the total production while the emerging sector contributes only 5%.

The tomato is the second most important and popular vegetable crop after potatoes in South Africa, accounting for about 18.2 % of the gross value of vegetable production in the country (DAFF, 2014). It is not only cultivated commercially but also grown by subsistence, resource-poor farmers and home gardeners. The industry employs approximately 22,500 people who jointly have at least 135,000 dependents (DAFF, 2014).

The study area was chosen based on its importance for tomato production in South Africa. Limpopo Province, which covers the northernmost region of South Africa, is the major tomato growing province in South Africa and accounts for 75% of the total national area planted under tomato. The National Agricultural Marketing Council's NAMC (2012) also shows that the majority of South Africa's tomato production happens in the Limpopo Province particularly by one major commercial producer. As tomato is not only cultivated commercially but also grown by subsistence, resource poor farmers and home gardeners, this study focuses on the well institutionalized and economically strong tomato production and marketing channels due to the players' dominant presence in the sector. The DAFF (2016) further confirms that the tomato commercial sector's contribution to total production multiplies that of the emerging sector by a factor of nineteen.

Considering that several studies on price transmission in agricultural produce markets have been conducted in South Africa, (e.g., Mashamaite and Moholwa, 2005; Funke, 2006; Jooste *et al*., 2006; Kirsten and Cutts, 2006, Alemu and Ogundeji, 2010; Abidoye and Labuschagne, 2013), it is evident that the subject is of considerable economic interest. However, there is a gap in the literature on price transmission in tomato markets of Limpopo, despite the province's importance in the South African tomato industry. No up to date empirical evidence has been provided to explain vertical price linkages between farm, wholesale, and retail levels for Limpopo produced tomatoes. Furthermore, it is unclear at what stage tomato prices are determined along the marketing chain. This lack of information hampers government efforts to manage any probable anti-competitive behaviour amongst market players. The question of how tomato marketing efficiency can be enhanced therefore remains unanswered given that very little awareness exists on the market's current economic performance.

The next sections will provide the limitations of the study, a discussion of price transmission, and some of the relevant methodological approaches used in food markets. Conceptual frameworks, analytical techniques as well as model specifications used in this paper are also presented. In addition, the paper will provide a discussion of the research findings, summary and conclusion.

Limitations of the study

While a large gap between upstream and downstream prices may be considered as a standard occurrence in most markets, it may not be too obvious how much the exact contribution of each total margin component is. Rather, this study does not focus on isolating the actual individual impacts of each middlemen activity or identify other additional costs incurred in transferring produce from the farm gate to the final consumer. Secondly, this study does not capture the impact of seasonal price fluctuations due to lack of readily accessible historical price information, particularly at the farm gate and retail levels. More work may be needed to first create open access price databases for probable future analyses. The researcher is also aware of the perishability nature of tomato which might complicate the product's marketing dynamics. This study, however, does not measure the exact influence of product perishability since the study scope is delineated to only one product which invalidates any basis for comparison.

Price transmission and associated methodological approaches in food markets

Price transmission is a broad concept that can be referred to in different ways. According to Colman (1995), price transmission is the extent to which a price series at one location causes changes in, or correlates with price changes at another location. Rapsomanikis *et al*. (2003) explained the concept based on three components, which are co-movement and completeness of adjustment (CCA), dynamics and speed of adjustment (DSA) and asymmetry of response (AoR). CCA entails full transmission of changes in prices in one market to the other at all points of time. DSA covers the process and rate at which change occurs in one market filter to the other market levels. The final component, AoR, entails whether upward and downward movements in the price at one level are either symmetrically or asymmetrically transmitted to the other levels.

Similarly, Vavra and Goodwin (2005) gave four aspects as a basis for assessing asymmetric price transmission. The first is the aspect of magnitude, which is concerned with how big the response is at each level as a result of a shock of a given size at another level. The aspect of speed measures how fast or slow the adjustment process is and also considers whether there are significant lags in adjustment. The nature of price transmission considers whether any adjustment that follows positive and negative shocks at a particular marketing level displays asymmetry. The fourth aspect, which is direction, ascertains the extent to which adjustments contrast, depending on whether a shock is transmitted upwards or downwards the supply chain. Considering the four aforementioned aspects, four types of asymmetry can therefore be analyzed which include positive and negative asymmetry, asymmetry in magnitude, asymmetry in speed and asymmetry in both speed and magnitude.
The literature on price transmission in agriculture offers several methodologies that one may apply in related studies. Several papers provide a broad spectrum of data types applicable to analysing vertical and spatial price linkages in agricultural markets. While Guvheya *et al*. (1998) used daily and weekly tomato price data that was collected from field surveys, Moghaddasi (2009) considered monthly price observations at farm and retail levels for two Iranian agricultural products, namely pistachio and date. Jeder, Naimi, and Oueslati (2017) analysed the transmission between retail and producer prices for main vegetable crops in Tunisia by means of annual time series data.

This study employed primary and secondary time series data. Random but consecutive daily tomato prices were collected concurrently at the farm gate, wholesale and retail levels for mixed grades of cooking tomatoes. The longitudinal dataset comprised a sample size of 50 price observations collected through daily market surveys which ran between May 2012 and 31 July 2012. All three data sets were measured in South African Rands/kg. The farm gate prices were observed at the Mooketsi farm gate, owned by the largest tomato producer in the southern hemisphere, while retail prices were gathered from five purposively selected major vegetable retailers operating in South Africa's northernmost provincial capital city, Polokwane. Furthermore, the study considered the National Fresh Produce Market daily tomato prices as a proxy variable for wholesale prices as a result of the absence of an active wholesale market within the borders of the study area.

For decades, several analytical techniques have been applied in various price transmission studies across the literature. For instance, Guvheya *et al*. (1998) utilized the Houck procedure to test price transmission between wholesale and farm prices. Through use of an error correction model, Minot (2011) investigated the degree of transmission of world food prices to markets in Sub- Saharan Africa. Abdulai (2000) studied spatial price transmission and asymmetry in the Ghanaian maize markets using threshold cointegration tests by allowing for asymmetric adjustments towards long-run equilibrium relationships between price series.

In Malaysia, Mohamed *et al*. (1996) were able to determine the point of price determination along eleven vegetable value chains by examining the nature of price linkages of vegetables between farm, wholesale, and retail levels in selected vegetable markets through performing the Granger causality tests. Similarly, Moghaddasi (2009) was able to ascertain the optimal lag lengths of price causal relationships between successive marketing levels. An application of the Houck procedure also assisted them to ascertain whether price increases were transmitted more completely than price decreases in the Iranian date and pistachio markets. The study was also able to test for the speed of positive and negative price adjustments by means of an error correction model. .
Bolotova and Novakovic (2011) noted five major causes of price asymmetry between levels, as revealed in several literatures, which include the presence of market power and coordinated conduct of firms with market power, government regulations, repricing and transaction costs, shifts in supply and demand, and imperfect information. According to Karantininis *et al*. (2011), positive price transmission occurs when agents in the intermediate stages in the food supply chain exercise market power and thus influence the price adjustment process to their advantage both upstream towards farmers and downstream towards the final consumer. The market structure of each level and information advantage of one level compared to another are stated in Mohamed *et al*. (1996) as determinants of the efficiency of price transmission between the two levels.

Girapunthong *et al*. (2004) explored price asymmetry in the United States fresh tomato market. In an effort to analyze price relationships between the farm, wholesale and retail levels of this industry, the authors employed Ward's (1982) price asymmetry model. Granger causality tests were first used to determine the direction of causality. It was then established that price transmission was unidirectional from the farm to the retail level. The study did not find any asymmetric response in price transmission between producers and retailers. However, evidence of price asymmetry was found between wholesalers and

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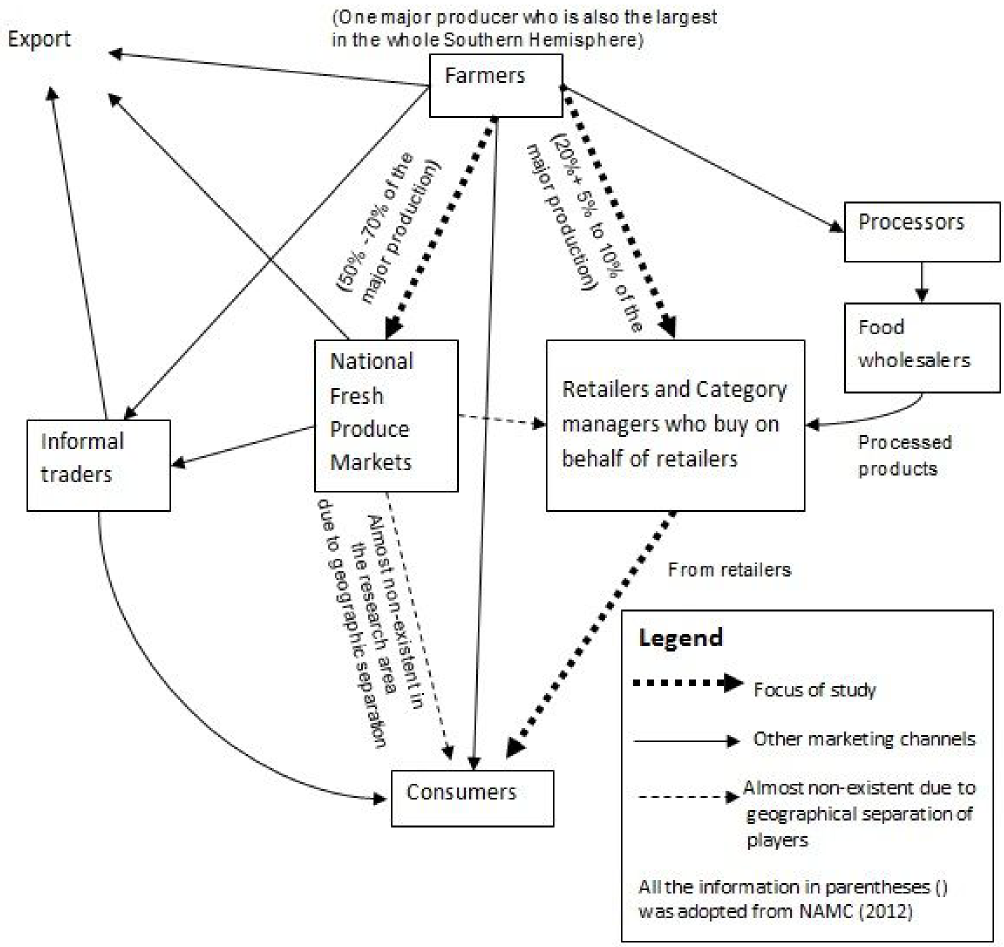

Figure 1: Marketing channels of tomato in the most northern province of South Africa, Adapted from: DAFF (2014); NAMC (2012)

both producers and retailers. Such evidence was interpreted to indicate that retail prices respond more when wholesale prices increase than when they decrease. On the other hand, wholesale prices were found to react more to decreasing producer prices than when they rise. This study adopts the Houck procedure mainly due to its ability to directly consider the impact of positive and negative variations of the time series data, as also alluded by Frey and Manera (2005). While the Houck procedure is normally chosen for its simplicity, Moghaddasi (2009) cautions that the approach should be applied consistently with unit root and cointegration tests to avoid spurious correlation problems. For more reliable inferences, the Houck procedure of analysing price asymmetry was therefore applied for data points which were not cointegrated according to the Johansen cointegration tests. The Error Correction approach was also adopted as a way to capture the positive and negative components of the residuals from the cointegration relationship between respective data series.

Conceptual framework and analytical techniques

Data collection was guided by the conceptual mapping of the key marketing channels shown in Figure 1. Figure 1 shows the different marketing channels that are evident in the most northern province of South Africa. The market has only one major producer who is also the largest in the southern hemisphere. According to NAMC (2012), 50%-70% of the major production is sent to the wholesale platforms called National Produce Markets. These national markets are geographically quite far from the study area and, as a result, none of the studied retailers usually buy from there. However, most of the local retailers use the national market prices as a benchmark for business decision making. NAMC (2012) further shows that 20% + 5% to 10% of the major production volume is sold directly to local retailers.

Figure 2 illustrates a consolidated mind map of the analytical conceptual framework applicable to this study and is in line with the literature on analyzing price transmission. Firstly, each pair of price series was examined for order of integration using the Augmented Dickey-Fuller tests (Dickey and Fuller, 1979). This was completed to ensure that the price series were integrated in the same order before the error correction model could be applied. Prior to performing Granger causality tests, the VAR Lag

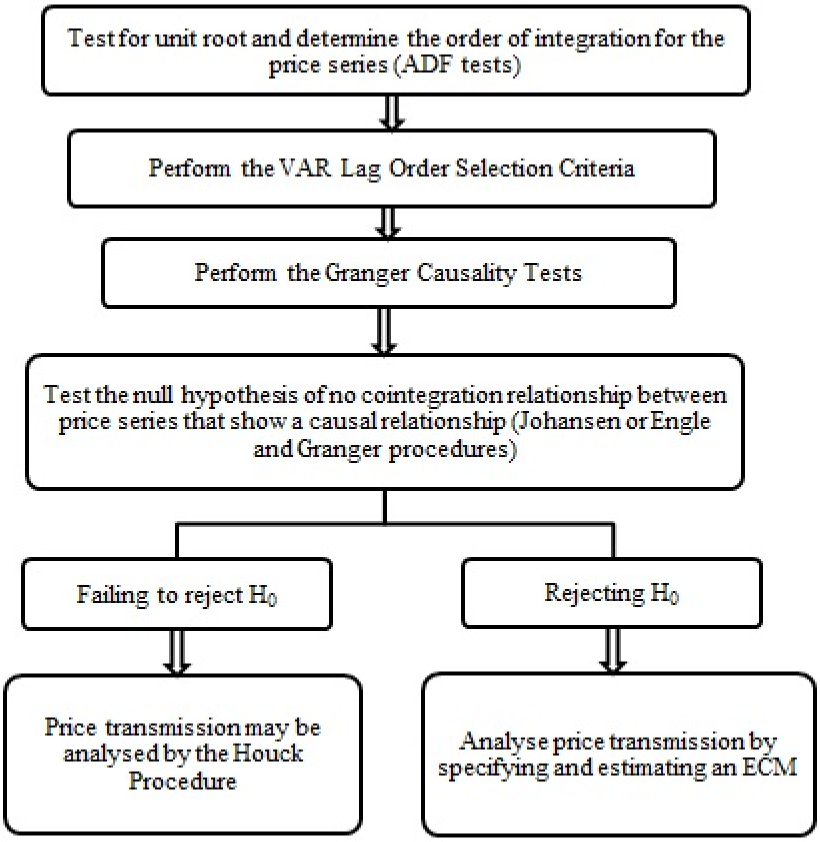

Figure 2: Mind map for analyzing vertical price linkages in the tomato value chain of Northern South Africa, Adapted from: Granger (1969); Houck (1977); Dickey and Fuller (1979); Ward (1982); Engle and Granger (1987); Moghaddasi (2009)

Order Selection Criteria was employed to determine the optimal lag length (Granger, 1969). Co-integration tests were then performed to check the presence of any long run co-integration relationships between the price series. In the event of any price series found to be co-integrated, price transmission would be analyzed using the Error Correction Model. Otherwise, a relatively less intricate alternative, such as the Houck procedure, would be applied.

Analytical model specification

$$\Delta WP_t = a_0 + a_1 iFP_t + a_2 iFP_t \qquad (1)$$

where ΔWP_t is the change in wholesale price, iFP_t is the increase in farm price, and dFP_t is the decrease in farm price. Given the relationship portrayed in equation 1, asymmetry or non-reversibility would occur in ΔWP_t if according to the t-test $a_1 \neq a_2$.

In order to ascertain whether retailers adjust to farm price increases the same way they do for decreases, an Error Correction Model (ECM) was used in accordance with the Engle and Granger (1987) two-step procedure. Equation 2 was specified and estimated using Ordinary Least Squares,

$$\Delta lnRP_t = \alpha_1 + \Sigma^5_{i=1}\beta_i \Delta lnRP_{t-i} + \Sigma^5_{j=0}\phi_j \Delta lnFP_{t-j} + \alpha^+_2 ECT^+_{t-1} + \alpha^-_2 ECT^-_{t-1} + \varepsilon_\tau \quad (2)$$

where $\Delta lnRP_t$ = first differenced lnRP in period (t), $\Sigma^5_{i=1}\beta_i \Delta lnRP_{t-i}$ = the 1st, 2nd…5th lagged first-differenced values of lnRP, $\Sigma^5_{j=0}\phi_j \Delta lnFP_{t-j}$ = the 1st, 2nd…5th lagged first-differenced values of lnFP as well as its value in period (t), ECT^+_{t-1} = positive error correction terms lagged by one period, and ECT^-_{t-1} = negative error correction terms lagged by one period, α_1, β_i, ϕ_j, α^+_2, α^-_2 are estimated coefficients.

In equation 2, the error correction terms (ECT_{t-1}) measure deviations from the long-run equilibrium between farm level and retail level prices. ECT_{t-1} was segmented into ECT^+_{t-1} and ECT^-_{t-1} to facilitate the test for asymmetric price transmission.

Results and Discussions

The price of tomatoes over the period varied across the marketing chain under analysis, as shown in Figure 3, where the highest weekly average farm gate price was R1.85/kg, while the lowest was R1/kg, and the average

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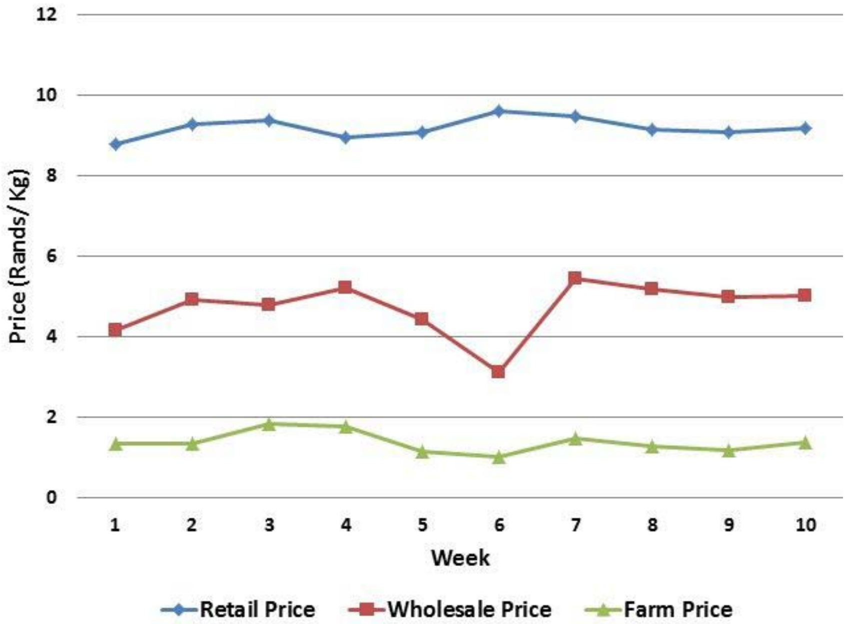

Figure 3: The general tomato marketing margin structure in northern South Africa, Source: Fieldwork, May 2012 - July 2012

farm gate price for the whole period was R1.37/kg. The highest wholesale price was R5.45/kg, while the lowest was R3.10/kg and the whole period average was R4.73/kg. The highest retail price was R9.60/kg, while the lowest was R8.79/kg and the average was R9.20/kg. Figure 3 shows the five day weekly average margin structure. The relationship between weekly average prices of tomato at three levels is presented in absolute terms. The vertical distance between each price reflects the estimated margins between the respective price levels at each point in time.

The Granger Causality tests suggested two unidirectional causality relationships: from farm gate to retail level and from farm gate to wholesale level. Furthermore, farm gate prices were found to influence both wholesale and retail prices, which may be symptomatic that prices are determined at the farm level along the tomato marketing chain. Farm gate and retail price series were found to be co-integrated, thus justifying the use of the Error Correction procedure. On the other hand, there was no cointegration relationship found between farm gate and wholesale price series, thus, the Houck Approach was applied giving the following results in Table 1.

Table 1 shows that for 46 degrees of freedom, the calculated t-value (0.01714) does not exceed the critical t -value even beyond the 0.98 significance level for a two-tailed test. Therefore, we cannot reject the null hypothesis that the coefficients for farm price increases and decreases are equal. Thus, it can be concluded that the effect of increasing farm gate prices on wholesale or retail prices is statistically not different from that of decreasing prices. In simpler terms, price transmission from the farm level to the wholesale stage of Limpopo produced tomatoes is symmetric, which indicates some degree of efficiency in price information dissemination between these two levels.

The results in Table 2 provide empirical evidence of price asymmetry between the farm and the retail levels of the tomato marketing chain in northern South Africa. The positive error correction term (ECT^{+}_{t-1}) is statistically significant at a level of 5%, whereas the negative error correction term (ECT^{-}_{t-1}) is insignificant. This may suggest that upstream price increases for the tomato value chain in northern South Africa cause a more substantial movement in downstream prices than is the case when upstream prices decrease.

A comparison between the absolute values of the estimated coefficients of both ECTs (0.676644 and 0.415170) reveals that positive error correction terms provoke appreciably greater changes in retail prices than negative error correction terms. These results may point to the possible existence of an asymmetric price transmission between the farm level and the retail level in the tomato value chain of northern South Africa. Another explanation of this asymmetry could be the likely profit maximizing behaviour of retailers, who seemingly react faster to profit threatening situations than to price movements that favor them. Such inter-temporal profit

Table 1: Results of the Houck procedure for Farm-Wholesale Price transmission

Variable	Coefficient	Std. Error	t-statistic	Prob.
Constant	0.010911	0.175601	0.062134	0.9507
iFPt	0.929481	1.418683	0.655171	0.5156
dFPt	0.890212	1.567608	0.567879	0.5729
Var (a1) 2.012662		Var (a2) 2.457396		Cov (a1,a2) -0.388695
Degrees of freedom 46			Calculated t-value (0.01714)	

Table 2: Empirical Results of the Error Correction Model for Farm-Retail Price Transmission

Variable	Coefficient	Std. Error	t-Statistic	Prob.
Constant (α_1)	0.005415	0.006804	0.795845	0.4324
$\Delta lnRP_{t-1}$	0.036386	0.219423	0.165826	0.8694
$\Delta lnRP_{t-2}$	0.071384	0.193480	0.368947	0.7148
$\Delta lnRP_{t-3}$	0.292458	0.179287	1.631227	0.1133
$\Delta lnRP_{t-4}$	0.212064	0.165728	1.279590	0.2105
$\Delta lnRP_{t-5}$	0.137968	0.166174	0.830265	0.4129
$\Delta lnFP_{t}$	-0.034864	0.039986	-0.871903	0.3902
$\Delta lnFP_{t-1}$	-0.010371	0.036280	-0.285854	0.7770
$\Delta lnFP_{t-2}$	0.055103	0.033396	1.649987	0.1094
$\Delta lnFP_{t-3}$	0.068348	0.034386	1.987644	0.0560*
$\Delta lnFP_{t-4}$	0.030513	0.036056	0.846270	0.4041
$\Delta lnFP_{t-5}$	-0.119578	0.035030	-3.413587	0.0019***
ECT^{+}_{t-1}	-0.676644	0.276938	-2.443305	0.0207**
ECT^{-}_{t-1}	-0.415170	0.448446	-0.925797	0.3619
R-squared 0.580677			Durbin Watson stat. 2.350648	

maximization conduct by retailers may also be a result of their reluctance to incur any price adjustment costs, which are usually fixed despite of whether the upstream price movements are positive or negative. As retailers evade price adjustment expenses, there can be a situation where consumers still spend more for a unit of tomatoes from the retailers whether farm gate prices have increased or decreased. This finding concurs with Jaffry (2005), who indicated that in the presence of asymmetric price transmission, consumers may not benefit from

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price reductions which tend not to be fully passed on to them. Ben-Kaabia and Gil (2007) also confer that retailers usually benefit from any shock that affects supply or demand conditions, regardless of whether it is positive or negative. Retailers react faster when their margins are squeezed than when they are stretched (Kirsten and Cutts, 2006).

Conclusion

While it is evident that the market for tomatoes in South Africa has been characterized by soaring consumer prices at times, this study targeted at providing a possible empirical explanation of the relationship between upstream and downstream prices for this commodity. Efforts were aimed at investigating price transmission along the marketing chain for tomatoes in northern South Africa by using data collected simultaneously at three marketing levels: farm gate, wholesale and retail. It was also key to answer the question on whether intermediaries in the tomato value chain of northern South Africa pass more completely any cost increases while transmitting less entirely cost savings.

Findings indicated the existence of a large gap between what consumers paid for each unit of tomatoes purchased from retailers, and the amount farmers received for the same quantity from retailers in northern South Africa. Furthermore, the producers' portion of the consumers' Rand was low in absolute terms, since according to the study results, a major part of tomato retail prices constituted total gross marketing margins. However, further studies may need to focus on measuring the individual impacts of each middlemen activity, as well as making market data available on the actual cost drivers along each specific tomato value chain.

Overall, price transmission was found to be more efficient between the farm gate and the wholesale levels than between the farm gate and retail levels. In response to farm price changes, retailers tend to make quicker positive price adjustments than negative price adjustments when there are price increases at the farm level, rather than price reductions, as retailers' profits are threatened whenever farm prices increase than when they decrease. Differences in efficiency of price transmission between various market levels could constitute a result of dissimilarity in the way marketing information is transmitted amongst market players. For instance, the major wholesalers of tomato in South Africa, such as the National Fresh Produce Markets with their online price publishing system, are very transparent as far as price information is concerned. Such price information symmetry allows every stakeholder to be aware of the market prices of tomato over time which leaves no room for artificial price manipulation by the wholesalers. It is recommended that a similar price broadcasting system be adopted by retailers so that their price information is made public at times to facilitate the price monitoring exercise.

The asymmetric price transmission detected between the farm and retail levels may prompt one to conclude that the responsible authorities, such as the National Marketing Council and the Republic of South Africa's National and Provincial Departments of Agriculture, may need to intervene through intensified monitoring of pricing mechanisms in the South African tomato retail markets. This can be achieved through making it compulsory for all key retailers and commercial farmers to individually submit periodic food pricing reports to the provincial agricultural marketing directorates. The government may also launch an online survey system where all key players are mandated to update their pricing information on an ongoing basis to facilitate the gathering of central market information. Such data collection will also help build an open access food price database that will facilitate and ease food economic analyses.

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Conflict of Interests

The author hereby declares that there are no conflicts of interests.

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Research Paper

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Pollination of Acacia woodlands and honey production by honey bees in Kitui, Kenya

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Honey bee, Honey production, Pollination, Acacia, Livelihoods, Conservation

Abstract

Acacia woodlands dominate arid and semi-arid areas across the world and are an important source of livelihood supporting activities. This is also the case in Kenya, where the Acacia woodlands are under pressure, partly due to the extractive activities that generate household income, such as collection of fuelwood, building poles, charcoal burning and livestock fodder. There is an apparent dilemma between the extractive and non-extractive use of the Acacia woodlands, and a need to develop income generating activities that also conserve and support the natural basis. Honey production is a widespread activity in Kenyan Acacia woodland areas, and thus a potential candidate for the task, but information on pollination of wild plants in the tropics in relation to livelihood sustenance and natural resource conservation is scarce. Therefore, this study investigates to what extent honey bees (*Apis mellifera*) visit and pollinate *Acacia brevispica* in Kitui County, Kenya. The study also assesses the occurrence of Acacia pollen types in honeys produced within the study area. The results show that honey bees were the most numerous flower visitor and pollinator of *A. brevispica*, while Acacia pollen was the predominant pollen type in the sampled honeys. This shows that honey bees provide pollination services to *A. brevispica* for the return of pollen and nectar for the production of honey, which is a source of income for local households. Understanding the link between pollination of *A. brevispica* and honey production can help to facilitate conservation efforts for the benefit of the woodlands and its inherent biodiversity as well as for local livelihoods.

Introduction

Plant-pollinator interactions contribute to biological diversity, maintenance of ecosystem functions, agricultural productivity, food security and livelihoods (Potts et al., 2003, 2010). Unfortunately, this interaction is threatened by human induced factors, such as urbanization (Potts et al., 2010), intensification of agricultural land use, intensive use of chemicals, and the introduction of genetically modified and alien species (Krebs, Wilson, Bradbury & Siriwardena, 1999; Richards, 2001; Ricketts, 2004; Tscharntke, Klein, Kruess, Steffan-Dewenter & Thies, 2005). Habitat loss and fragmentation may result in reduced pollinator diversity (Vazquez & Simberloff, 2002) and lower number of pollinators (Lennartsson, 2002; Potts et al., 2003), pollination deficits and low seed output due to pollen limitation (Jennersten, 1988); all of which negatively affect plant populations as well as agricultural production (Foley et al., 2005). However, human activities may also have a positive role in the plant-pollinator interaction, such as pollination services of managed bees in natural environments (Chamberlain & Schlising, 2008).

Mutual interactions between plants and pollinators can be complex and is associated with a number of factors.

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For instance, visitation rates of a plant by pollinators can be influenced by factors, such as climatic conditions, pollinator type and characteristics, and flower morphology and physiology (Conner & Rush, 1996; Richards, 2001; Ushimaru, Watanabe & Nakata, 2007). Previous studies have shown that there is a relationship between pollination limitation, visitation rate and abundance of pollinators (Herrera, 2000; Larson & Barrett, 1999; Morandin & Winston, 2005). Pollinators can be specialists, i.e. pollinators visiting one or specific plant species, but generalists that visit and pollinate many and diverse plant species are more common (Ghazoul, 2006; Johnson & Steiner, 2000). The honey bee is an example of a generalist pollinator (Aslan, Liang, Galindo, Hill & Topete, 2016; Olesen & Jordano, 2002).

Forests surrounding agricultural farms have been found to have a positive impact on abundance and diversity of pollinators (Klein, Cunningham, Bos & Steffan-Dewenter, 2008; Ricketts, 2004) as well as the survival of the plants (Kolehmainen & Mutikainen, 2006). This has also been indicated in studies conducted in Kenya (Karanja, Njoroge, Gikungu & Newton, 2010). Forests provide important foraging, nesting, roosting and mating sites for most pollinators (Ricketts, 2004; Roubik, 1995). Absence or change in natural habitats/forests interrupts plant-pollinator relationships (Goulson, Nicholls & Rotheray, 2015; Richards, 2001; Winfree, Aguilar, Vazquez, Lebuhn & Aizen, 2009) and may lead to depressed agricultural output and loss of livelihoods (Karanja et al., 2010). Besides creating a habitat for pollinators, forested areas also play an important role for many rural communities, especially in areas with widespread poverty and subsistence agriculture where collection of non-timber forest products is undertaken as an important livelihood activity (Wunder, Angelsen & Belcher, 2014). Such activities are undertaken in dry forests and woodlands in Kenya where trees in the natural environment have a supporting role for rural livelihoods. However, these areas may come under pressure from the very same activities (Barrow & Mlenge, 2003; Kiage, Liu, Walker, Lam & Huh, 2007; Mureithi, Verdoodt, Njoka, Gachene & Ranst, 2016).

As such, maintenance of pollination services and pollinator populations is a significant task, not only geared towards conservation of natural resources (Stone, Raine, Prescott & Willmer, 2003), but also for the sake of maintaining or enhancing agricultural productivity, food security and rural livelihoods. In order to understand the importance of pollination services for the regeneration and production of different plant species, natural and managed, information on the flower visitors and their importance for seed or fruit set is required (Martins, 2008; Stone et al., 2003).

Acacias spp. are thorny plant species in the Fabaceae family, which thrive well in tropical and subtropical habitats, particularly in arid and semi-arid regions (Marshall et al., 2012; Ross, 1981; Stone et al., 2003). The genera includes woody shrubs and trees, which can translate to bushlands and forests (Ross & Gordon-Gray, 1966). The growth form of the plant species are attributed to climatic and edaphic conditions in the growing area. Acacia plants are self-incompatible and exhibit little or no self-fertilization (Muona, Morant & Bell, 1991) and rely on insects for pollination (Stone et al., 2003; Tandon & Shivanna, 2001; Tybirk, 1993). Floral rewards of Acacia plants to their visitors are nectar and pollen (Stone et al., 2003; Stone, Willmer & Rowe, 1998), and they are important food resources to a variety of insects (Adgaba et al., 2017; Martins, 2014). Bees, wasps, flies and butterflies have been documented as flower visitors of most Acacia spp. (Stone et al., 2003; Tybirk, 1993).

Acacia trees also constitute an important wild resource for rural communities in dry zone areas across the world (Moncur, Mitchell, Fripp & Kleinschmidt, 1995). The trees are used for livestock fodder (Nyambati, Sollenberger, Karue & Musimba, 2006), medicine (Ibrahim & Ibrahim, 1998; Wanzala, Syombua & Alwala, 2016), timber, poles, charcoal and fuel wood (Dlamini & Geldenhuys, 2009; Stone et al., 2003, 1998). Acacia plants also supports life forms as well as provide pollen and nectar for production of honey (Martins, 2014). This is the case in the Arid and Semi-arid Lands (ASAL) of Kenya, where a number of *Acacia spp.* are important sources for livelihood. In Kitui County, Kenya, trials have also been undertaken for the production of wild silk, but the Acacia woodlands are mostly known for the production of a unique quality honey, which has a high demand and good reputation in the region of production as well as at a national level (Egelyng et al., 2017). Honey production in the area forms an important source of livelihoods for the local communities where several beekeeping groups have been established.

Acacia woodlands in Kitui have been under pressure, due to extractive activities which are undertaken by local households for income generation (ICIPE, 2009). These activities include collection of fuel-wood, building poles, charcoal burning, and livestock fodder. The Ministry of Agriculture in Kitui, County, Kenya has emphasized the need to develop non-extractive and woodland 'friendly' income generating activities. Therefore, the local communities in the area have been supported in undertaking honey production activities for income generation. However, little is known on the relationship between pollination of *Acacia spp*. in Kitui and livelihood sustenance as well as conservation of natural resources.

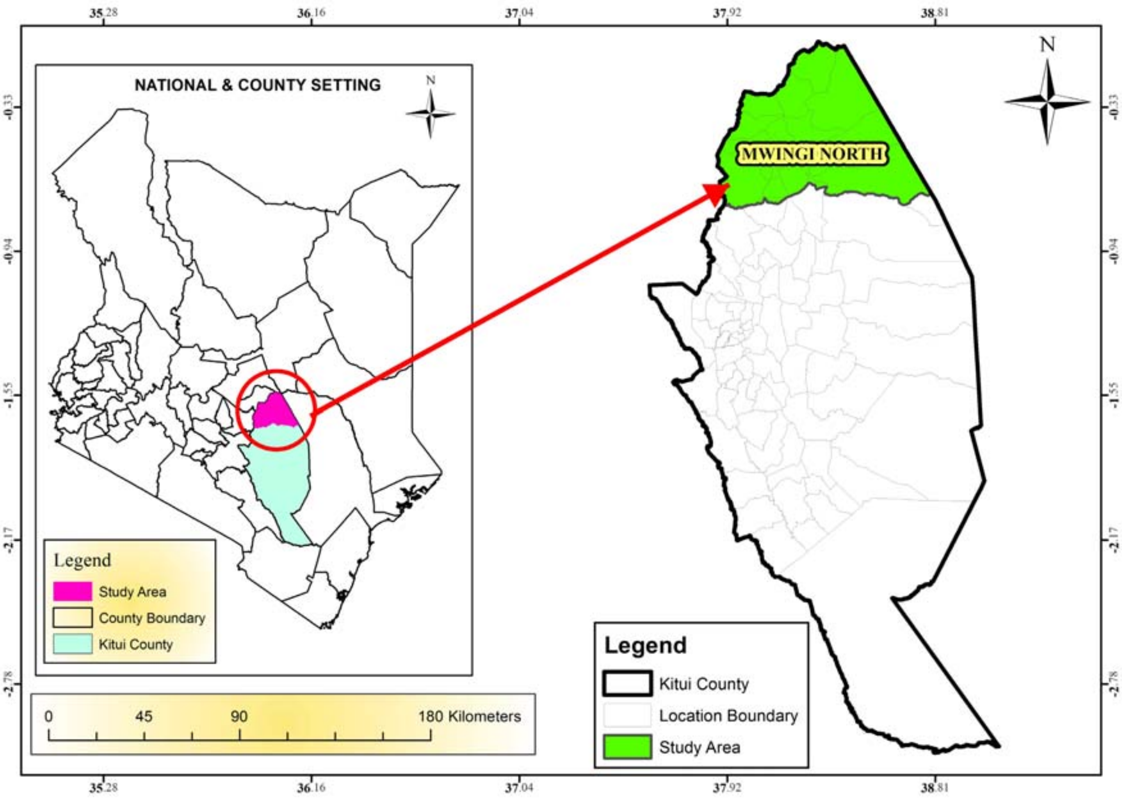

Figure 1: A map of Kenya showing the study area (Kitui County) and sampling site (Mwingi North) (Source: Own compilation using data which was derived from survey of Kenya)

Furthermore, information on the utilization of *Acacia spp.*, and other surrounding vegetation by honey bees, in production of honey has not been documented. Understanding the link between visitation and pollination of *Acacia spp.* by honey bees, and the production of good quality honey can increase the awareness of the double role of beekeeping for income generation and pollination services to a woodland species under pressure. Therefore, this study aims to investigate to what extent honey bees visit and pollinate the naturally occurring woody plant, *A. brevispica*, which is one of the key species in the Acacia woodlands in Kitui County, Kenya.

Methodology

Study area

This study was carried out between January-May, 2016 in Kitui, Kenya, which falls within the semi-arid zone in Kenya (Figure 1). The County is located between latitudes 0^0 10^i and 3^0 0^i South and longitudes 37^0 50^i and 39^0 0^i East. Kitui is home to the Mumoni tropical forest reserve, which is adjacent to communal and private lands. Beekeepers place their hives in the forest, communal and private lands. Small scale agriculture, pastoralism, and beekeeping are the main sources of livelihoods in the study area (Ayuya et al., 2015; ICIPE, 2009).

Acacia and *Commiphora spp*. are the most dominant and widespread vegetation types in the study area (ICIPE, 2009). Various Acacia plants flower at different times during the rainy season. During the studied season, *A. brevispica* was the only flowering *Acacia spp*. *A. brevispica* was also the dominant flowering plant with conspicuous white flowers that could be observed throughout the study area. A smaller part of the study area is covered with small-scale agricultural farms where crops, such as mangoes, cassava, sorghum, millet, beans, and maize are grown. Temperatures in the study area range between 14^0C and 34^0C, with September being the hottest month when most bee flora dries up. The area experiences frequent droughts due to erratic and unreliable rainfall, ranging between 500-700 mm annually.

Data Collection

Abundance and diversity of flower visitors and pollinators of *A. brevispica*

To determine diversity, abundance of flower visitors and pollinators of *A. brevispica*, observations were carried out in four farms (2 ha each) located 2 km from the Mumoni forest in Mwingi North, Kitui. The distance between the farms was 1 Km. Each of the four farms had similar plant species belonging to different families, including Acacia trees. In each farm, 14 Acacia trees were selected based

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Table 1: Composition of flower visitors and abundance

		Number of visitors on observed flowers				
Visitor/Study Site	**Insect group**	**Farm 1**	**Farm 2**	**Farm 3**	**Farm 4**	**Total number of visits on flowers**
Apis mellifera	Honey bee	109	126	148	159	542
Lipotriches spp.	Bee			8		8
Lasioglossum spp.	Bee		11			11
Braunsapis spp.	Bee	1	10			11
Belenois aurota	Butterfly	16	31	9	9	65
Polistes spp	Wasp	1				1
Calliphora spp	Fly	1	6			7
Syrphus spp	Fly			5		5

on their form and structure. In each of the tree, five branches with similar form, size, and shape were selected in the middle of the crown for observation. Each branch had an average of five flowers. Pollinator exclusion bags (nylon mesh of 10µm hole size) were placed around the selected branches when flowers were at bud stage to prevent unobserved flower visitors (Hansted, Grout, Eilenberg, Dencker & Toldam-Andersen, 2012; Martins, 2008; Martins & Johnson, 2009). Flower visitor observations were carried out between 8 a.m. to 4 p.m. on sunny days when flower visitors were active. The exclusion bags were opened once and each flower was observed until it had been visited by a single visitor. Flower visitors were observed for a maximum of 10 minutes after which re-bagging was done to ensure that no other pollinator visited the flowers. Flower visitors, their abundance and behaviour on the flowers were recorded. Visited flowers were marked using a ribbon tape and numbered differently for easy monitoring. The pollinator exclusion bags were removed after fading of the visited and bagged flowers. The mature pods on the marked branches were harvested, opened and the number of seeds counted. To investigate if A. *brevispica* would set seed after self-pollination, 20 branches from the trees were selected and bagged for observation of flower visitors. Additional 20 branches were marked and left uncovered to allow for open pollination. Seed set (the proportion of flowers that developed seeds) was calculated as the number of seeds counted/potential ovules.

Collection of honey samples for pollen analysis

To assess the occurrence of Acacia pollen in honey produced within the study area, eight unprocessed honey samples were collected from hives placed in areas surrounding the four test farms. The honey samples were harvested and collected during the study season. Each sample was placed in a clean and closely tight container to avoid contamination. Containers with the honey samples were labelled and stored under room temperature (25°C).

Pollen analysis was carried out by a specialist in the Palynology section at the National Museums of Kenya. The analysis was executed based on methods of melissopalynology described by Louveaux, Maurizio and Vorwohl (1978) and Von Der Ohe, Oddo, Piana, Morlot and Martin (2004). Pollen grains were extracted from collected honey samples and identified using a collection of reference pollen slides and photographic atlas. Pollen types found in the honey were recorded and occurrence percentages in each honey sample were calculated. All of the honey samples were analyzed during the same time period to ensure uniform conditions and comparability.

Results

Flower visitors of *A. brevispica* and seed set

Flowers of *A. brevispica* were visited by different insect groups belonging to three orders; Hymenoptera (bees and wasps), Diptera (flies), and Lepidoptera (butterflies)

Table 2: Seed set (%) for *A. brevispica* flowers exposed to different visitors (open pollination) and those visited once by honey bees

	Seed Set (%)	
Site	**Flowers pollinated honey bees**	**Open pollinated**
Farm 1	29.56	50.47
Farm 2	34.66	63.28
Farm 3	30.60	49.56
Farm 4	40.83	60.75
Mean	**33.91 (±0.33)**	**56.01 (±0.19)**

(Table 1). Bees were the most diverse groups of insects visiting *A. brevispica*, with honey bees being the most frequent visitors (Table 1). Aggression of honey bees was observed on occasions where other visitors made an effort to land on flowers in which honeybees were foraging.

Seed set in *A. brevispica* was only recorded in the flowers visited by honey bees and those left for open pollination throughout the flowering period. No seed set was found in flowers excluded from visitors, or flowers visited by other insects, such as solitary bees (i.e. *Lipotriches spp., Lasioglossum spp. and Braunsapis spp.*), butterflies, wasps, and flies. On average, flowers visited by honey bees only had a seed set of 33.9% (n= 280), while flowers left for open pollination, and thus possibly visited by any local pollinator had a 56.0% (n=20) seed set (Table 2).

Pollen types found in honey samples collected from study area

A total of 22 pollen types, belonging to 14 plant families were, observed in the honey samples. Of these, 21 were identified to genus level and only one to species level (Table 3). Of the pollen type identified, two were from agricultural crops, namely Sorghum and *Zea mays*. Acacia pollen was the predominant pollen type (>45%) in all of the honey samples, thus the most important floral resource for honey bees in this study. The Acacia pollen were certainly from *A. brevispica* since it was the only flowering *Acacia spp*. in the study area during the studied season. Other pollen types were represented as secondary pollen (16-45%), important minor pollen (3-15%), and minor pollen (<3%) (Jones & Bryant, 2014; Louveaux et al., 1978).

Discussion

Honey bees were the most abundant insects visiting *A. brevispica*. Similar observations were made in other Acacia visitation studies in Hawaii (Aslan et al., 2016), Mexico (Raine, Pierson & Stone, 2007; Raine, Willmer & Stone, 2002) and India (Tandon & Shivanna, 2001). The abundance of honey bees visiting *A. brevispica* in Kitui was attributed to the presence of colonized bee hives, which results from beekeeping activities within the study area as well as the presence of wild honey bees in tree hollows within the natural environment of the study site. Honey bees also have a good communication system (waggle dance) and they take advantage of flowers with promising floral rewards which can be foraged on with minimal cost (time and energy) (Couvillon et al., 2012).

The results of this study also show that visitation of *A. brevispica* by honeybees contributed to the reproduction of the plant. Recorded seed set from flowers visited by honey bees, unlike those visited by other insects, was attributed to aggression of honey bees during foraging (Badano & Vergara, 2011; Martins, 2004; Vergara & Badano, 2009), where honey bees were observed chasing away other visitors who tried to forage on the flowers of *A. brevispica*. Reproduction success was also attributed to contact of honey bees with stamens and pistil of flowers during foraging. This result concurs with findings of other studies which noted that honey bees competes with other pollinators for floral resources (Schaffer et al., 1983; Steffan-Dewenter & Tscharntke, 2000; Thomson, 2006). Furthermore, their presence in agricultural fields may decrease the diversity of other floral visitors who are likely to be efficient pollinators (Badano & Vergara, 2011). Zero seed set in flowers visited by solitary bees, butterflies, wasps and flies suggest that organisms visiting plants may not necessarily pollinate the flower, even though they collect the floral rewards (Spears,1983; Stone et al., 2003). Higher seed set in open pollinated flowers may be as a result of the flowers being exposed to more visits or by diverse visitors. Previous studies note that visitation frequency of plants by pollinators (Aslan et al., 2016; Benachour & Louadi, 2013; Couvillon et al.,

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Table 3: Pollen types found in the honey collected from the study site

Pollen Type	Family	Pollen Type Percentage							
		HS1	HS2	HS3	HS4	HS5	HS6	HS7	HS8
Acacia spp.	Fabaceae	64	62	48	69	55	65	53	46
Justicia spp.	Acanthaceae	1		5	1	3		2	3
Leucas spp.	Lamiaceae	10	2		2	6	4	3	3
Ocimum spp.	Lamiaceae	17		13	10	5	8	4	7
Maesa spp.	Myrsinaceae	1		5		6		1	2
Sorghum spp.	Poaceae		2					1	
Cyphostemma spp.	Vitaceae	1							1
Euphorbia spp.	Euphorbiaceae	1	6	4	6	10	1	3	4
Allophylus spp.	Sapindaceae	1						1	1
Vernonia spp.	Asteraceae	3	18	10	2	3	8	10	7
Ageratum spp.	Asteraceae		1					1	
Solanum spp.	Solanaceae		2						1
Aspilia spp.	Asteraceae		4	10				3	5
Cucumis spp.	Cucurbitaceae			5		3	3	2	
Leonotis spp.	Lamiaceae				5			4	2
Ipomoea spp.	Convolvulaceae				1	3	2	2	3
Maerua spp.	Capparaceae				1				
Ricinus spp.	Euphorbiaceae					5	2		2
Commelina spp.	Commelinaceae						2	1	
Acalypha spp.	Euphorbiaceae						1	2	1
Zea mays	Poaceae	1			2				2
Bidens spp.	Asteraceae		2				4	3	

2015) and diversity of visitors (Stone et al., 2003; Winfree et al., 2009) enhance successful pollination. Lack of seed set on flowers that were excluded from pollinators implies that *A. brevispica* requires pollination for reproductive success (Harsh, 2000).

Occurrence of Acacia pollen types in the honeys collected from the study area confirm that Acacia plants are an important floral resource for bees, as also noted by Martins (2014). Results also indicated that honeybees have the ability to forage on a great diversity of flowering plants, including agricultural crops (Martins, 2004; Roubik, 1992; Villanueva-G & Roubik, 2004; Waser, Chittka, Prince, Williams & Ollerton, 1996) for their survival and reproduction (Roubik, 1992). Higher pollen percentages of Acacia pollen types, as compared to other pollen types (Table 3), could be attributed to honey bees preferences for *A. brevispica* as well as their availability and floral rewards offered by the plants (Fidalgo & Kleinert, 2010; Roubik, 1993).

The results of this study represent an opportunity to link pollination of Acacia woodlands, in this case *A. brevispica*, to both an income generating activity as well as to the contribution of the regeneration of the woodlands through pollination services by the honey bees. Given the current focus on sustainable development of arid and semi-arid areas by the Government of Kenya (2010), benefits derived from interactions between honey bees and Acacia woodlands could form an example of the necessity for sustainable utilization and conservation of dry land forests ecosystems in Kenya. All of the honeys sampled were classified as unifloral honey (i.e. Acacia honey), based on the predominant Acacia pollen type. Acacia honey from Kitui has a high reputation and demand as well as price premium in the market, which is attributed to the quality of the honey based on its link to origin (Egelyng et al., 2017). Fetching premium prices from Acacia honey can form an incentive for producers to conserve Acacia woodlands and other bee floral resources in order to enhance sustainable production. This has been the case for Oku white honey from Cameroon, which fetches premium prices based on its acidic flavour and unique white colour; characteristics which are attributed to two dominant white flower plants, namely *Nuxia congesta* and *Schefflera abyssinica*, present in the Oku forest (WIPO, 2014). To sustain production of Oku honey, producers and other actors within its production region have made efforts in enhancing regeneration and conservation of bee floral sources (WIPO, 2014). Increased benefits from honey production are likely to increase honey production activities, and to some extent, this may result in environmental pressure. There is, therefore, a need for policy support in beekeeping for honey production and pollination.

Conclusion

Findings of this study indicate that honey bees are important pollinators of a natural woody plant, *A. brevispica*, and are also an important floral source in honey production. Encouraging beekeeping in the study area for honey production can lead to pollination of the woodlands, thereby facilitating conservation of bees, their food resources and other biodiversity as well as local livelihoods. Therefore, this study suggests that conservation initiatives in the study area need to incorporate sustainable beekeeping practices. The results of this study also creates an opportunity to market honeys produced in the study area using labels which indicate a link of a product to the geographical origin, such as floral sources, for the honeys. This is anticipated to enhance product premium prices, which would create incentives for natural resource conservation and sustained production.

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Conflict of Interests

The authors hereby declare that there is no conflict of interests.

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Sorghum for corn: Water in the age of climate change

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Climate change, Water, Corn, Sorghum, Drought resistant, Water management

Abstract

This paper discusses corn and sorghum growth in the United States with regard to moisture utilization. Current climate change research predicts changing temperature and moisture cycles in geographic regions employed for agriculture. This research project investigates crop management practices that may reduce irrigation needs while maintaining a food supply necessary to feed a growing world population under these predicted changes. By comparing the response of yellow field corn to red grain sorghum, we hypothesize that sorghum yields will be less affected by predicted changes in rainfall events and thus require minimal additional irrigation. To test our hypothesis, we vary the timing of watering events for two different patches of corn and sorghum. We find that sorghum is the more drought resistant crop, making it more suited to fare with the predictions of climate change and in the fight for a more food secure world.

Introduction

In the United States, the major feed grains are corn, sorghum, barley, and oats. Corn accounts for over 95 percent of total feed grain production and use, making it the primary U.S. feed grain (USDA ERS, 2018). The United States is the world's largest corn producer, exporting between 10 and 20 percent of annual production (USDA ERS, 2018). Corn production utilizes over 90 million acres of land in the U.S. (USDA ERS, 2018). Corn also finds its way into virtually every type of processed product one can imagine, including starch, sweeteners, corn oil, beverage and industrial alcohol, and fuel ethanol (USDA ERS, 2018). An alternate crop that can replace corn on those 90 million acres is sorghum. Sorghum has similar feed properties to corn, and it has been noted the energy value of sorghum is between 90 - 100% the energy value of corn (Etuk et. al., 2012). It has also been noted that sorghum sweeteners can replace corn sweeteners currently used in the food and beverage industry (Pirgari, 2007). Due primarily to financial considerations, however, corn production far exceeds that of sorghum in the United States (Taylor, 2013). This is due to the fact that corn is heavily subsidized by the U.S. government, making the market price of corn cheaper than the cost of production (Fields, 2004). In other words, farmers are much more likely to be guaranteed to be paid for growing corn and other heavily subsidized commodities than other crops. This profitability translates into acres planted; to compare, only 6.04 million acres were used in 2018 for sorghum production (USDA ERS, 2018). However, the U.S. remains the world's top exporter of sorghum, with an estimated 73.6% of global exports in 2016 (U.S. Grains Council, 2017). The good news on this front is that the gap in profitability between the two crops is changing, and in some cases, actually favoring switching from corn to sorghum (Spiegel, 2015).

Climate change research reveals that rainfall patterns will increase in variability, creating the possibility for

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Figure 1: Silk stage **(**Photo credit Joy Youwakim)

more extreme weather events with droughts and famines on one extreme and floods and hurricanes on the other (Seager *et al*., 2007; Meehl *et al*., 2000; EPA, 2016). This more extreme variation in temperature and precipitation can prevent efficient crop growth. One evident example was the corn yield across the U.S. corn belt in 2010 and 2012, during which high nighttime temperatures contributed to smaller yields (EPA, 2016). In terms of monetary loss, Michigan forfeited $220 million in the cherry sales of 2012 due to premature budding caused by a warm winter (EPA, 2016). For farmers, this means a higher probability of losing their crops due to lack of ability to fund (as well as supply) supplemental irrigation or to protect against floods. Drier and hotter temperatures mean more consistently dry soil as well as inconsistent growth seasons. Extreme and unpredictable rainfall and wind events speak for themselves simply in terms of crop safety. Although some crops are resilient enough to come back after intense storms, this cannot be guaranteed.

The effects of climate change can already be seen today through invariable weather patterns across the world. Parts of the Northern Hemisphere have been experiencing a premature arrival of spring-like conditions, which have led to earlier dates of snowmelt and increased river flows. Consequently, summer and fall, the seasons with the highest water demand, are being affected by a reduced availability of freshwater. From 1900 to 2002, the Sahel region of Africa has been experiencing higher drought conditions (NASA, 2010). This has been proven according to the Palmer Drought Severity Index, which is a measure of soil moisture using precipitation measurements and rough estimates of changes in evaporation (NASA, 2010). Specifically, in the United States, most of corn and sorghum production occurs in the Great Plains region, and the irrigation depends on the Ogallala Aquifer, which is declining in water levels (Taylor, 2013).

By 2050, it is predicted that seventy percent of the world's population will live in urban areas, and although fertility rates are slowing in several countries, the global population is expected to reach 9.6 billion by 2050 and 11.2 billion by 2100 (United Nations, 2015). Also by 2050, feeding a planet of 9 billion people will require an estimated 50 percent increase in agricultural production and a 15 percent increase in water withdrawals (Khokhar, 2017). Over 70 percent of freshwater is used for agriculture in most regions of the world (Khokhar, 2017). This means we very quickly need to become efficient at

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Figure 2: Tasseling and heading out stage (Photo credit Joy Youwakim)

growing food with minimal resources such as water and arable land. In addition to enhancing water use efficiency of irrigation methods (Howell, 2001), it is essential to select crops that optimize the conversion of water into grain (Spiegel, 2015). The dual threats of precipitation and temperature changes make finding water efficient crops that can handle irregular irrigation imperative. The purpose of this research is to simulate climate change in a controlled, yet natural environment, and observe the effects on both corn and sorghum, ceteris paribus.

Methodology

Two rows of both yellow dent corn and Mennonite sorghum (milo) were planted in tandem with thirty inches of soil between the rows on April 19th, 2016 in Liberty Hill, Texas. Both rows contained an equal amount of both crops, as pictured below.

As the seeds germinated, they spent six weeks in the ground with no additional irrigation or covering. Fertilizer and pesticides were not utilized. On May 21st, the plants were covered with a black tarp to prevent external rainfall from penetrating the soil, and a drip liner was snaked around the plants in order to control irrigation.
In this study, the irrigation cycle is modeled by the following differential equation:

$$dY_{pot}/dF=-\lambda|F_{opt}\ -F|\ (F>=0),\ Y_{pot}\ (F_{opt})=Y_{max}$$

Here, Y_{pot} is the potential yield per plant, Y_{max} is the maximum yield per plant, F_{opt} is the optimal frequency (measured in weeks) of precipitation (using optimal amount of water), and F is the experiment frequency ($F=1=F_{opt}$ for our weekly watering, F=2 for our biweekly watering), and λ is a constant of proportionality. In our experimental case, $F >= F_{opt}$, thus:

$$dY_{pot}/dF=\lambda(F_{opt}-F)\ (F>=0),\ Y_{pot}\ (F_{opt})=Y_{max}$$

Solving yields

$$Y_{pot}=\lambda\ (FF_{opt}-1/2\ F\hat{}2)+C.$$

Solving for C;

$$Y_{pot}=\lambda\ (FF_{opt}-1/2\ F\hat{}2)+(Y_{max}-\lambda\ 1/2\ F\hat{}2_{opt}).$$

Assuming F_{opt} = 1(one week),then we have

$$Y_{pot}=\lambda(F-1/2\ F\hat{}2)+(Y_{max}-\lambda/2).$$

Using our data, we should be able to determine λ .

Table 1: Corn and Sorghum Yield and Growth based on Irrigation Variation

Final Total Yields	Corn	Sorghum
1 inch	2.435 lb.	.420 lb
2 inches	1.78 lb	.365 lb
Yield Decrease	27%	13%

Table 2: Corn Height by Irrigation Date

Irrigation Dates	Corn Heights
April 19th	0 feet
May 21st	3-4 ft
June 18th	6-7 ft
June 24th	10 ft

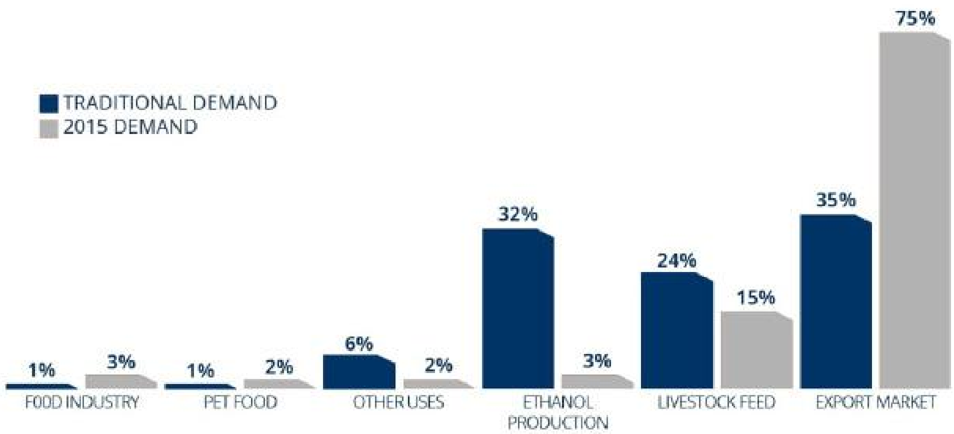

Figure 3: United Sorghum Checkoff Program 2015 Demand Comparison of Sorghum (Sorghum Markets Gain Momentum. (2016, May 02) Retrieved from http://www.sorghumcheckoff.com/news-and-media/newsroom/2016/05/02/markets-gain-momentum/ (15.09.2018)

This mathematical model implies that the change in yield potential for a plant is proportional to the difference between optimal frequency of watering events (rainfall, irrigation) and the actual frequency of watering events. The parameter lambda depends on the crop. A large value of lambda is indicative of crops where a small change in watering event frequency has a large effect on plant yield, whereas a small lambda would be indicative of a crop whose plant yield is fairly resistant to small changes in watering event frequency.

On June 11th, we began irrigating the first row weekly for one hour per week (at one time) in order to give it approximately an inch of water. The second row was watered bi-monthly (every two weeks), but received the same amount of water, two inches in a time span of two hours in one sitting. In the silk stage, which occurs about eight weeks after crop inception, we observed near equivalent height of both the climate change and control rows. In the tasseling and heading out stage the height difference was more clearly apparent, with a

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visible difference of about 6 inches of advantage to the control group. Pictured below are the silk stage on the left (Photo 1) and tasseling and heading out stage on the right (Photo 2).

Results

On July 30th, we were able to harvest both our corn and sorghum. We randomly harvested seven cobs of corn from each of the rows, and seven heads of sorghum from each row. The weekly irrigated corn weight amounted to 2.435 pounds, whereas the bi-monthly corn amounted to 1.78 pounds. The weekly irrigated sorghum weight amounted to .420 pounds, and the bi-monthly sorghum amounted to .365 pounds. These numbers portrayed a 13% yield decrease for sorghum, and a more substantial 27% decrease in corn yield. These findings reveal that sorghum is more suited to fare with the anticipated agricultural effects of climate change than corn.

Using these data, we can estimate lambda from the mathematical equation given above.

Corn:
Sorghum:

$1.78/7= \lambda(2-1/2\cdot4)+(2.435/7-\lambda/2)$
$.365/7= \lambda(2-1/2\cdot4)+(.420/7-\lambda/2)$

The resulting lambda for corn is .187 while the resulting lambda for sorghum is .016, demonstrating the larger discrepancy in corn yield loss due to changes in watering event frequency.

Conclusion

Sorghum is fungible to corn in terms of usage. It has benefits for livestock feed and its uses are largely diverse, ranging from ethanol to being used as a sweetener. The advantage of using sorghum for ethanol is that it produces the same amount of product per bushel, while using one- third less water than its counterpart (National Sorghum Producers, 2016). Furthermore, as proven by this research, sorghum fares better under moisture variability, which means less loss of crops and resources for farmers.

The U.S. errs on the side of low sorghum production for food due to the large amount of federal corn subsidies. U.S. crop subsidies for corn summed approximately $90 billion between 1995 and 2010, still excluding ethanol subsidies and mandates, which assisted in the increase of the price of corn (Foley, 2013). This also explains the choice to use sorghum more in ethanol production and the export market than in the food industry.

Concerning economic and environmental measures, choosing to grow corn in place of sorghum simply does not make sense. U.S. corn consumes an estimated 5.6 cubic miles per year of irrigation water withdrawn from America's rivers and aquifers (Foley, 2013). Choosing to grow more sorghum in place of corn will save on both costs and environmental damage due to water usage. One reason sorghum is not grown in place of corn is for fear of lack of marketable quality. For example, there's no "sorghum on the cob" recipe on Food Network. It is a food crop with popularity in Eastern hemisphere countries, such as Egypt and Ethiopia, where it is used to make breads (injera), cereals, and molasses. However, sorghum can be popped, used in salads, and even in some alcoholic drinks due to its sweetening capabilities. Once the gateway to sorghum flour is open, there is nothing to stop one from making delicious, gluten-free sorghum cookies, muffins, and pancakes. The options with this crop are endless, making it possible to be subsidized in the same way that corn is in the U.S., if not more so.

Corn's depletion of water resources is unsustainable for future resource allocation (Foley, 2013). This research shows that it would be prudent to grow sorghum in place of corn for the simple reason that the effects of variability of rainfall will be much less severe for sorghum than for corn (i.e. the comparison of lambda values). The quantitative value of growing a crop that can endure the same predicted weather conditions of the foreseeable future and have minimal yield loss are immense, especially in the United States due to our reliance on corn for livestock feed and its versatile nature as a sweetener (high fructose corn syrup, etc.). If we must rely on a grain to use in so many diverse roles, it should at least be one that conserves water.

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Conflict of Interests

The authors hereby declare that there is no conflict of interests.

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Seaweed farming as a sustainable livelihood option for northern coastal communities in Sri Lanka

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Sea Weed Farming, Sustainable livelihood, Financial feasibility, Coastal communities, Constraints

Abstract

Sri Lanka has recently contributed to the growing significance of seaweed farming in the globe. This study attempted to assess the financial feasibility, employment generation, perceived importance, social acceptability and major constraints associated with seaweed farming in the Northern part of Sri Lanka. The study sample included 160 seaweed farmers from the area. A questionnaire survey, in-depth interviews and focus group discussions were conducted to collect data and information. Descriptive analytical, investment evaluation and constraint analysis techniques were employed in data analysis. Both the economic viability indicators and employment generation were estimated for an average of 25 seaweed rafts. The estimated net present value (at a 20% discount rate) was US $ 253 (implying an Internal rate of return [IRR] = 43%), while the benefit-cost ratio was 1.19. The employment generation of seaweed farming at the study area has been estimated at 3,392 man days (1,280 man days plus 2,112 woman days) per annum. Among the prevailing livelihood activities, seaweed farming received the second highest perceived importance of the farmers followed by fishing. The constraint analysis disclosed poor quality of planting materials, distortions in the market, improper aquatic environments, and poor post-harvest handling as major constraints of seaweed farming. The results established considerable financial feasibility and social acceptance of seaweed farming, allowing it to identify as a sustainable livelihood option for Northern coastal communities. Furthermore, the study leads to recommend seaweed farming as a system to replicate in other potential areas in the country. It also suggests making adjustments in the cultivation season, offering problem related extension and training programs, introducing a flexible purchasing mechanism, and establishing more collaborative actions among key stakeholders as solutions for the identified constraints.

Introduction

The coastline of Sri Lanka measures approximately 1700 km, which contains many different varieties of seaweeds. About 320 seaweed species belonging to different families have been identified by different scientists (Duraitarnam, 1961; Barton, 1903; Boergensen, 1936). Two species of seaweed, namely Gracilaria edulis and G. verrucosa, commonly known as 'Ceylon moss' are found in coastal areas of Kalpitiya, Trincomalee, and Mannar areas (Duraitarnam and Medcof, 1955). Since 1800s, naturally collected Gracilaria spp have been exported from Sri Lanka (Duraitarnam, 1963), and a growing export market was identified thereafter. Furthermore, a small percentage of dried seaweeds is sold locally, while a good demand for packed Gracilaria spp can be identified in Islamic festive season in Sri Lanka. In 1987, Jayasuriya reported Gracilaria spp as a popular food item among fishermen, especially in producing areas, and was domestically consumed as porridge and a jelly drink.

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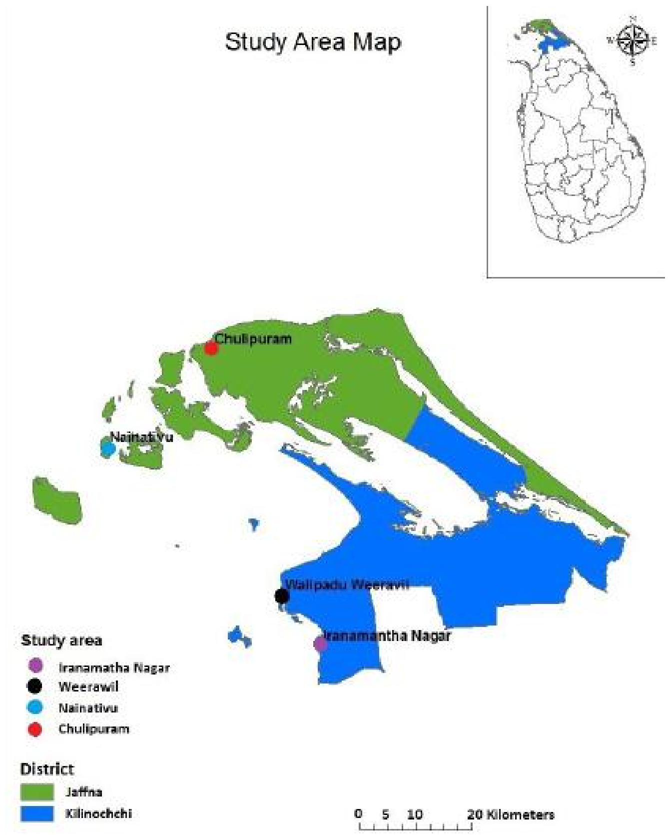

Figure 01: Map of the study area (Source: Authors' illustration)

More recently, seaweed farming in Sri Lanka has seen significant growth and continues to expand globally, thanks to its relatively higher productivity led by a variety of coastal resources (Nayanananda, 2007). In the coastal belt, fishery is the conventional economic activity of the majority, surpassing all other agricultural aspects. The fishing escalates on a daily basis due to the involvement of a heavily populated coastal community. However, such operations are becoming more unsustainable with destructive fishing practices coupled with illegal fishery issues (Madanayaka, 2015) and communal clashes.

In order to create a sustainable coastal community, especially at geographically isolated, marginalized, and vulnerable locations, the creation of alternative (Thilepan and Thiruchelvam, 2011; Crawford, 2002) or sustainable livelihood options capable of unlocking the potential of oceans seems vital. Accordingly, resettled coastal communities, including Kilinochchi, Mannar, Jaffna, and Mullaitivu of Northern Sri Lanka have been actively involved in seaweed farming. In some countries, seaweed has already identified as a catalyst of social progression (Prado et al., 2012) in coastal communities providing substantial income while rendering extensive employment opportunities (Krishnan & Narayanakumar, 2010) to the farming households. Though major constraints, such as unfavorable weather and uncertain market condition (Valderrama et al., 2013) have negatively affected the progression of seaweed cultivation, yet majority has illustrated the potential of seaweed farming as a profitable commercial enterprise adding opportunities for value addition, integration, and earning much needed foreign exchange through exporting (Prado et al., 2012; Abowei & Ezekiel, 2013).

Previous studies have investigated the socio-economic impacts of seaweed farming at different levels of economic outcomes (Rebours et al., 2014). With reference to the Brazilian context, seaweed farming is identified as a significant source of income for individual households. Beyond the favorable economic effects on individual farm families, seaweed cultivation has extended beneficial effects on the entire economy of certain countries. For instance, it has contributed significantly to the economy of the Zanzibar Islands of Tanzania by becoming a leading foreign exchange earner that accounts for above 90 percent of Zanzibar's marine export products (Msuya, 2006). On the contrary, poor levels of economic performance of seaweed farming (Eklöf et al., 2012) has also been reported in some other locations. In Mexico, Seaweed farming is not attractive when compared to other fisheries, like sea urchin, which is not assuring a good livelihood for the growers (Rebours et al., 2014). In addition to income generation, previous studies (Crawford, 2002; Narayanakumar & Krishnan, 2011) have also identified the employment potential of seaweed farming, especially as a means of women empowerment in coastal

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Table 1: Sample Distribution

District	DS Division	GN Division	Sample Size
Kilinochchi	Poonakary	Walipadu Weeravil	40
		Iranamathanagar	30
Jaffna	Velanai	Chulipuram	40
	Islands South	Nainathivu	50
Total			160

(Source: Field survey, 2016)

communities (Msuya, 2006).

Though the basic technological package is similar across countries, the prevailing uneven development of the industry is largely owing to variations in farm prices and the scale of operations (Valderrama et al., 2015). As indicated by Eklöf et al. (2012), which refers to the seaweed farming in Chwaka Bay, such uneven developments coupled with various challenges, including varying environmental conditions (Msuya, 2012), uncertain markets (Valderrama et al., 2013), and poor institutional structures (Kim et al., 2017; Msuya, 2012) have negatively affected the social acceptability as well as the socio-economic sustainability of seaweed farming.

Still, it is vital to have a sound basis of information related to the performances, including economic viability in terms of financial feasibility, employment generation, and social acceptability of seaweed cultivation in coastal localities in order to identify it as a sustainable livelihood option and other potential expansion of coastal areas in Sri Lanka. Thus, this investigation was conducted to explore the socio-economic feasibility and viability of small-scale seaweed farming along Northern coasts of Sri Lanka.

Methodology

Study Area and Sample Selection

Two districts, namely Jaffna and Kilinochchi, which are located in the Northern Province of Sri Lanka, were intentionally selected for the study considering the presence of seaweed farmers (Figure 1). Afterwards, four Grama Niladhari (GN) divisions were selected called Walipadu Weerawil and Iranamathanagar from Kilinochchi district; and, Chulipuram and Nainathivu from Jaffna district. 160 seaweed farmers were randomly selected, representing different operational scales, such as small-scale (<25 rafts), medium-scale (25-50 rafts) and large-scale (>50 rafts). A raft is a flat buoyant structure of timber or other materials fastened together and is used as a floating platform. The scales were proportionality selected from each GN division that represents 40% of the total seaweed farmers (Table 1).

Data Collection

Data collection was carried out during the months of May to July 2016. Both primary and secondary data were collected in the study. Primary data were collected from the sample respondents, mainly through a questionnaire survey. Moreover, key personnel interviews, focus group discussions, and field observations were performed to acquire detailed information on measured aspects. Data were collected concerning the production process, cost of production, marketing aspects, farmer perceptions, and constraints of seaweed cultivation. A multidisciplinary team of researchers, including a sociologist, economist, and biologist were involved in the data collection process. Secondary data required for the study were extracted from both published and unpublished sources.

Data analysis

The conventional tabular analysis was completed by working out item-wise expenditure and revenue to assess the returns from the representative seaweed farms, which consist of a habitat system of 25 floating bamboo-rafts (12×12). The calculation took into account all the costs of production, including cash and non-cash costs. Cash costs included direct expenses needed in the production of seaweed, whilst non-cash items included depreciation, interest on investment, and unpaid family labour occupied in the seaweed farm. Depreciation costs were computed using the straight-line method and assumed no residual value at the end of the useful life of 03 years for the initial investment. Still, interest on investment was charged at 7 % per annum, parallel to the rates adopted by commercial banks. Total revenue was worked out by multiplying the total production by the average farm-gate price. Net return was solved as the difference between total revenue and the total cost of production.

Investment evaluation techniques were used to assess the financial feasibility of seaweed cultivation. Payback period and rate of return on investment were used as undiscounted measures, whilst net present value (NPV), internal rate of return (IRR), and benefit cost ratio (BCR) were used as discounted measures of investment worthiness (Engle, 2010; Gittinger, 1982; Firdausy & Tisdell, 1991; Narayankumar & Krishnan, 2011). Since undiscounted measures fail to take the timing of the benefit stream into account adequately, it is recommended to use a mix of both discounted and undiscounted measures to cover every aspect of the investment (Engle, 2010; Gittinger, 1982).

Investment options with shorter payback periods were preferred as it quickly identifies investment options with immediate cash returns. The rate of return on investment indicates what percentage of the investment is received from the average annual net returns, but fails to consider the size and timing of the annual earnings (Engle, 2010). Net present value, as a discounted cash flow technique, measures the present worth of the income stream generated by an investment, therefore, investments with a positive NPV would be accepted. The internal rate of return indicates the discount rate that makes incremental cash flow equal to zero, and investments with an IRR greater than the discount rate is considered as profitable. The benefit-cost ratio was obtained by dividing the present worth of the benefit stream by the present worth of the cost stream. The BCR of one or greater at the opportunity cost of capital was preferred. The discount rate, which represents the rate of return that the investor could have earned by investing on other available options, is important for a reasonable evaluation. Accordingly, a 20% discount rate was adopted for the analysis. Furthermore, the study considered that each cultivation cycle remains for 45 days, with four cultivation cycles for the first and third-year, and five cycles for the second year. The equations used in the analysis are given below.

$$\text{Pay} - \text{back period (years)} = \frac{\text{Investment}}{\text{Average annual net revenue}} \quad (1)$$

$$\text{Rate of return on investment} = \frac{\text{Average annual net revenue} \times 100}{\text{Investment}} \quad (2)$$

$$\text{NPV} = \sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} \quad (3)$$

IRR: the discount rate (i) such that,

$$\sum_{t=1}^{t=n} \frac{B_t - C_t}{(1+i)^t} = 0 \quad (4)$$

$$\text{BCR} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \quad (5)$$

Where,
B_t= benefit in each year, C_t= cost in each year, t = terminal year, n = number of years, i = discount rate

The additional employment generation from seaweed farming was estimated by adapting the procedure proposed by Satyanarayana and Rao (2013) for Groundnut cultivation. The package of practices undertaken in seaweed farming was identified through a review of literature and discussion with experts. The response of each interviewee was recorded in terms of approximate time spent in hours for each practice within the package, which was then summed up separately and converted into man days. The study assumed that one woman-day

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$$\text{Percent Position} = \frac{100 \times (R_{ij} - 0.5)}{N_j}$$

Where,
R_{ij} = Rank given to i^{th} constraint by the j^{th} individual
N_j = Number of constraints ranked by the j^{th} individual

equals 0.6 man-days and considered 08 hours as the standard working hours per day.

The Garrett's ranking technique (Christy, 2014; Zalkuwi *et al*., 2015; Dhanavandan, 2016) was exercised to detect the judgment of the farmers about the constraints faced by them in seaweed cultivation. Consequently, respondents were inquired to assign the rank for all the constraints and the outcome of ranking was converted into percent position by using the formula 6.

The percent position estimated was switched into scores by using Garrett's Table (Garrett, 1926). Then for every constraint, the scores of each individual were inputted and total value of scores and respective mean values of scores were computed. The constraint having the highest mean value was considered as the most significant factor.

The perceived importance of farmers towards different production activities was measured by assigning a perceived ordinal rank (Crawford & Shalli, 2007) and farmers

Table 2: Annual cost and returns of seaweed farming (per average of 25 rafts)

Initial investment	Unit	Quantity	Per unit price (US $)	Total Value (US $)	Share (%)
Planting materials	kg	1500	0.03	44.34	6.93
Seaweed growing structures	raft	25	213.70	534.26	83.55
Miscellaneous	-	-	-	2.96	0.46
Labour for installation	md*	5	5.91	29.56	4.62
	wd**	8	3.55	28.38	4.44
A. Total initial investment				639.48	
Fixed cost					
Depreciation				178.09	81.39
Interest on investment (7%)				40.71	18.61
B. Total fixed cost				218.79	
Operating cost					
Maintenance Labour	wd**	12	3.55	42.56	47.37
Harvesting and drying Labour	md*	2	5.91	11.82	13.16
	wd**	6	3.55	21.28	23.68
Miscellaneous labour	wd**	4	3.55	14.19	15.79
C. Total operating cost				75.67	
D. Total cost of production(B+C)				308.65	
E. Gross revenue				638.45	
F. Net income (E - D)				329.80	

md* - man-days, wd** - woman-days

were requested to provide their view on each perceived rank.

Results and Discussion

Costs and returns of seaweed farming

Table 2 presents the annual costs and returns incurred by seaweed farming with respect to an average of 25 bamboo-rafts (12×12). Accordingly, the initial investment was estimated at US $ 639.50, mainly comprising the investment cost incurred in the construction of farming systems (84%) or rafts, which do not need to be replaced yearly. Generally, seedlings were sourced from the harvest of the earlier crop and a portion of the harvest is allocated as replanting biomass for the subsequent cycle. The total cost of production was estimated at US $ 308.65, comprising a fixed cost of US $ 218.80 (75% of the total cost of production), and an operating cost of US $ 89.86 (25 %). The non-cash expense of depreciation is high as the study assumes that the productive lifespan of a bamboo-raft is 03 years. Labour is the most common, or rather the only operating cost, for the majority of farmers involved in seaweed farming within the study area. With the exception of labour requirement for initial preparation, the operating cost covers labour for weeding, harvesting, drying, and maintenance. Though the present analysis considered the imputed value of unpaid family labour, in practice, labour expenses are low since farmers employ their own family members. Additionally, the opportunity cost of their employment may also be lower due to the scarcity of productive jobs at the coastal communities.

The average level of total production after a grown out period of 45 days equals to 250 kg of fresh seaweeds. Thus, a 10:1 ratio of fresh to dry weight generates 25 kg of dry seaweed. After removing all the impurities, the gross revenue was estimated as a yield of 24 kg of dried seaweed per raft and a farm-gate price of US $ 0.27 for the first-year and thereafter US $ 0.29. Consequently, the annual gross revenue was estimated at US $ 638.45 leading to an annual net income of US $ 329.80.

Financial feasibility of seaweed farming

Financial feasibility indicators were measured and are presented in Table 3. Accordingly, the net income for the first and second years were US $ 329.80 and US $ 555.62 respectively, leading to a payback period of 1.55 years, indicating moderate cash returns to the investment. Moreover, 67% of the initial investment (US $ 639.48) is covered by a Net Present Value (at 20% discount rate) of US $ 253.10 (implying an IRR of 43 %), while the benefit-cost ratio (BCR) was 1.19. Additionally, the financial feasibility of seaweed farming within Jaffna district (BCR=1.12) was relatively low compared to Kilinochchi district (BCR=1.43). This difference may be attributed to the more established nature of seaweed farming in Kilinochchi district. However, these indicators are less attractive compared to the previously reported studies of Padilla and Lampe (1989) and Narayankumar and Krishnan (2011), who refer to the seaweed industries of Philippine and India, respectively. This discrepancy could be explained by the difference in scale of production, where those countries are practicing large-scale production systems compared to the condition in Sri Lanka. Some scientists (Hurtado *et al*., 2001; Alin *et al*., 2015) have noted that the seasonality of cultivation affects the positivity of these indicators, where positive indicators are received during peak months, whilst negative values are obtained during lean periods. Therefore, under small-scale production, caution must be applied as the findings might not be transferable to already established, large-scale weed production systems. It could be argued that the present investigation considered all of the cash and non-cash expenses, such as unpaid family labour for calculations, however, in practice, most of the farmers fulfill labour requirements from the available family labour and the existing contract growing system which assists farmers in constructing seaweed growing structures. Therefore, seaweed growers may receive more benefits that are not interpreted from these theoretical estimations. Together, these results provide important insights to the improvement of the Sri Lankan seaweed industry as a financially profitable livelihood option for coastal communities.

The average level of total production after a grown out period of 45 days equals to 250 kg of fresh seaweeds. Thus, a 10:1 ratio of fresh to dry weight generates 25 kg of dry seaweed. After removing all the impurities, the gross revenue was estimated as a yield of 24 kg of dried seaweed per raft and a farm-gate price of US $ 0.25 (for the first-year and thereafter US $ 0.29). Consequently, the annual gross revenue was estimated at US $ 638.29 leading to an annual net income of US $ 329.72.

Financial feasibility of seaweed farming

Financial feasibility indicators were measured and are presented in Table 3. Accordingly, the net income for the first and second years were US $ 329.72 and US $555.49respectively, leading to a payback period of 1.55 years, indicating moderate cash returns to the investment. Moreover, 67% of the initial investment (US $ 639.33) is covered by a Net Present Value (at 20% discount rate) of US $ 253.04 (implying an IRR of 43 %), while the benefit-cost ratio (BCR) was 1.19. Additionally, the financial feasibility of seaweed farming within Jaffna district (BCR=1.12) was relatively low compared to

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Table 3: Financial feasibility indicators for seaweed farming (per average of 25 rafts)

Indicators	Unit	Year 1	Year 2	Year 3
Initial investment	US $	639.48	N/A	N/A
Total cost of production	US $	308.65	331.03	308.57
Gross returns	US $	638.45	886.52	709.21
Net income	US $	329.80	555.49	400.63
Payback period	Years	1.55		
Return on investment	Percent	67		
Net Present Value (20% discount rate)	US $	253.10		
Benefit Cost Ratio (20% discount rate)	Ratio	1.19		
IRR	Percent	43		

Table 4: Additional employment generation from seaweed farming (per average 25 rafts)

Management practice	Man/male-days	Woman-days
Site preparation	5	2
Seedlings selection and preparation	-	1
Hauling of seedlings	-	1
Planting	-	4
Care of crops	-	12
Harvesting	1.5	4
Hauling of produce	0.5	2
Drying	-	2
Packing	-	2
Total	7	30

Kilinochchi district (BCR=1.43). This difference may be attributed to the more established nature of seaweed farming in Kilinochchi district. However, these indicators are less attractive compared to the previously reported studies of Padilla and Lampe (1989) and Narayankumar and Krishnan (2011), who refer to the seaweed industries of Philippine and India, respectively. This discrepancy could be explained by the difference in scale of production, where those countries are practicing large-scale production systems compared to the condition in Sri Lanka. Some scientists (Hurtado *et al*., 2001; Alin *et al*., 2015) have noted that the seasonality of cultivation affects the positivity of these indicators, where positive indicators are received during peak months, whilst negative values are obtained during lean periods. Therefore, under small-scale production, caution must be applied as the findings might not be transferable to already established, large-scale weed production systems. It could be argued that the present investigation considered all of the cash and non-cash expenses, such as unpaid family labour for calculations, however, in practice, most of the farmers fulfill labour requirements from the available family labour and the existing contract growing system which assists farmers in constructing seaweed growing structures. Therefore, seaweed growers may receive more benefits that are not interpreted from these theoretical estimations. Together, these results provide important insights to the improvement of the Sri Lankan seaweed industry as a financially profitable livelihood option for coastal communities.

Table 5: Percent rank distribution of livelihood activities

Livelihood activity	Percentage of respondents(N=160)					Total
	Perceived ordinal rank					
	1	2	3	4	5	
Fishing	65.6	12.5	7.5	0.0	0.0	85.6
Seaweed	25	68.8	6.2	0.0	0.0	100.0
Hired labour	5	12.5	51.2	6.3	0.0	75.0
Livestock	0.0	3.1	18.8	26.3	3.1	51.3
Trading	2.5	3.1	10.0	10.6	6.3	32.5
Terrestrial farming	0.0	0.0	6.3	15.6	9.4	31.3
Government Employment	1.9	0.0	0.0	0.0	0.0	1.9
Total	100.0	100.0	100.0	58.8	18.8	

Source: Primary data processed, 2016

Employment generation

The results, as shown in Table 4, indicates that 25 man-days (07 man-days + 30 woman-days, assuming one woman-day equals 0.6 man-days) of additional employment opportunities are generated from an average of 25 seaweed rafts. This implies that approximately 100 man-days; 0.33 full-time equivalent jobs per year (assuming 300 working days per year) could be generated from well-managed 100 seaweed rafts. In this situation, a large-scale seaweed industry would generate abundant employment opportunities for the coastal communities. This employment potential of seaweed farming was observed in earlier studies of Hurtado (2013); Krishnan and Narayanakumar (2010); and, Narayankumar & Krishnan (2011).

It is obvious that the most labourious portions of seaweed farming are initial site preparation and the crop maintenance. In a family operation, all of the family members, including spouse and children, are working together on the farm. Therefore, only a small number of respondents were identified using hired labour only for the labourious activities. These findings may help us to understand the fact that the seaweed farming offers reasonable employment opportunities, particularly for the female farmers that can be effortlessly managed with their household activities.

Perceived importance towards seaweed farming

Among the prevailing livelihood activities, fishing received the highest perceived importance of the respondents. However, 94% of the respondents perceived seaweed as either first or second in importance (Table 5). A variety of perspectives were expressed when the respondents were requested to suggest reasons for their perceived importance towards seaweed farming. Accordingly, eight causative responses emerged from the study are the favorable income (95% respondents) and employment generation (87%), the ability to readily integrate with fishing (72%), instrumental in empowering women (65%), the existence of a contract farming system (60%), rapid return on investment (58%), requiring simple farming techniques (55%), and an alternative for deprivation of terrestrial lands for cultivation (52%).

The seaweed farming, as a favorable source of livelihood option, has provided relatively high and continuous income for the respondents. The additional income from outside of fisheries helps highly fishing-dependent communities to manage income losses during extended periods of declining fish catch. This livelihood diversification has reduced the risk of over-reliance on one income source. As an economically viable alternative and livelihood option (Narayankumar & Krishnan, 2011), seaweed farming has delivered a stable annual average income, ensuring a stable way of life for farmers of those who mainly depend on it. Altogether, the beneficial impact of income generation from seaweed farming improves household economic resilience and enables a sustainable way of life which uplifts the overall living standard of the farming communities (Crawford, 2002). Those who responded felt that they are more food secure after engaging in seaweed farming. Investments indicated other beneficial spin-offs on facilitating extra educational options, like tuition for the children, purchasing new housing, material assets (Crawford & Shalli, 2007), and other essential consumer goods. As indicated by Krishnan and Narayanakumar (2013), there is a beneficial influence

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of extra income generation from seaweed farming that facilitates more participation in social functions by the respondents. These findings confirm with Zacharia *et al*. (2015) and Tobisson (2013) on the role of seaweed farming in coastal livelihood improvement. According to Thilepan and Thiruchelvam (2011), to improve livelihoods of poor coastal communities in Sri Lanka, alternative non-traditional livelihoods are vital and it can, therefore, be assumed that the present study raises the possibility of seaweed farming in fulfilling these requirements.

The participants highlighted that the seaweed farming renders extensive employment opportunities (Rajasree & Gayathri, 2014; Crawford & Shalli, 2007), especially during initial preparation and harvesting stages, whilst there were some cases where all household members entered the workforce. This result is in agreement with the findings of Rajasree and Gayathri (2014), and Crawford and Shalli (2007), which showed the employment potential of seaweed farming. The possibility to develop diversified seaweed products locally will be an implication to generate more employment opportunities during post-harvest processing of seaweed. This view is supported by Abowei and Ezekiel (2013), who noted that seaweed farming is a solution for social problems, such as the high rate of under and unemployment, youth restiveness, and militancy in the Niger Delta. Similarly, considering the employment potential of seaweed farming, Narayankumar and Krishnan (2011) suggest that the government policy measures should encourage fishers, especially fisherwomen, to form self-help groups. Altogether, this finding has important implications for developing higher levels of employment-income-consumption relationships as indicated by Krishnan and Narayanakumar (2010) referring to the coastal communities in India.

The key personnel interviews and focus group discussions revealed that seaweed farming requires lesser time for its maintenance after planting and allows farmers to engage in other activities. Therefore, the farmers can easily integrate seaweed farming with conventional fishing (Abowei & Ezekiel, 2013). However, and consistent with Zamroni and Yamao (2011), there were some cases where fishing, the primary economic livelihood of fishermen, has already been replaced by seaweed farming as the main income source. As noted by Prado *et al*. (2012), integrated mariculture farming systems boost family productivity in the coastal environments. Thus, this finding has important implications for developing other possible integrated farming systems of seaweed at the local conditions.

Another common view amongst interviewees was that the seaweed farming is instrumental in empowering women in the coastal communities (Tobisson, 2013; Abowei & Ezekiel, 2013). This finding corroborates the ideas of Tobisson (2013), and Abowei and Ezekiel (2013), who emphasized the significance of seaweed farming in empowering women in the coastal communities. In addition, Rajasree and Gayathri (2014) noted that the seaweed farming is an economically sustainable livelihood option for fisherwomen, especially widowed fisherwomen. Generally, the shallow water seaweed farming, particularly planting, maintenance, and harvesting stages tend to be dominated among female farmers. The contribution of female farmers to the regular labour force reduces the cost of production, whilst the cash income is viewed to be mainly invested for tuition and purchasing modern housing materials (Rajasree & Gayathri, 2014).

The existing contract farming scheme builds up a contractual relationship among the buyer and seaweed farmers. Accordingly, the buyer initially provides extension facilities and planting materials, and commits to purchase seaweed at a pre-determined price, whilst the contracted farmer is liable to supply dried seaweed at a satisfactory quality. The participants assume that the product is purchased at a discounted price to cover-up the cost of materials provided and further argue that the existing payments are not properly compensating the efforts. In a study conducted by Zamroni and Yamao (2011), it was noted that the seaweed price fluctuates within the year. Consequently, the price decreased by 10% during the peak production period compared to the annual average price for seaweed, which increased by 20% during the lean production period, and remained stable during medium production periods. Though the existing contact growing system is not fully encouraging, it has reduced the financial risk for farmers by minimizing the price fluctuation of dried seaweed and avoids longer market chains. It can, therefore, be suggested to improve the prevailing contract growing system by concerning more on farmer satisfaction, rearranging basic seaweed price based on effort, and using non-price arrangements for farmers in meeting social obligations. These recommendations are in line with Krishnan and Narayanakumar (2013) who refer to the contract farming system in Indian seaweed industry. However, there is abundant room to effectively utilize the contract farming scheme to facilitate rapid expansion of seaweed farming in Sri Lanka.

The in-depth interviews indicated that rapid return on investment and employing simple farming techniques generate perceived importance for seaweed farming. Generally, the seaweed farming demands minimal com-

Table 6: Results of the constraint analysis

Constraint	Total Score	Rank	Percentage
Unfavorable weather	12536	1	19.59
Poor quality of planting materials	10673	2	16.68
Distortions in purchasing system	9408	3	14.70
Improper aquatic environments	8794	4	13.74
Poor post-harvest handling	7381	5	11.53
Occupational health hazards	6463	6	10.10
Damaged by predators	5033	7	7.86
Theft problem	3712	8	5.80

pulsory agro-inputs and easy maintenance. In comparison to other aquaculture industries, the technical aspect of the seaweed farming is easier to grasp. Thus, farmers can adapt learning by doing practice to improve the husbandry. Moreover, additional training and extension schedules can cause an immediate impact on the performance of seaweed farming. Altogether, these findings suggest a role for farmer groups or producer associations (Neish, 2013), which allows members to share labour and other material inputs towards the more effective functioning of individual seaweed farms.

Constraints for seaweed farming

The results, as shown in Table 6, indicate that the unfavorable weather pattern (19.6%), poor quality of planting materials (16.7%), distortions in the purchasing system (14.7%), improper aquatic environments (13.7%), poor post-harvest handling (11.5%), and predator damages (10.1%) are the major issues and challenges for the seaweed farming.

Seaweed farming, within the study area, is critically affected by the prevailing unfavorable weather condition that is mainly due to the seasonal changes accompanied by monsoonal weather pattern. As indicated by Zamroni and Yamao (2011), the monsoonal weather pattern is the most critical challenge faced by the Indonesian seaweed industry. Furthermore, both Hurtado *et al*. (2001) and Neish (2013) put forward that the seasonality impact is the major issue for sustained seaweed cultivation. The environmental condition is always changing due to this seasonal variation leading to heavy rains and other severe weather, like prolonged higher temperature periods. On average, the seaweed cultivation limits to four cultivation seasons per year, beginning from mid-May in every year and continuing to February in the following year totaling nine months. Cultivation during rest of the period is not possible due to prevailing high-temperature conditions and severe rainfalls. These unfavorable changes in the environmental conditions lead to variations in the harvesting time. Consequently, in many cases farmers have harvested seaweed before reaching harvestable size and age. Both the quality and measure of seaweed are highly affected by missing the best maturity stage of the plant. A comparative study on Indonesian seaweed farming by Valderrama *et al*. (2013) found that the monthly seaweed harvest of the best season is 2.8 times greater than the average, while it is only 42% during the worst periods. The growth and quality of seaweed can also be affected by the changes of water and salinity levels during dilution of seawater with rainwater. The strong waves and currents prevailing within the study area have also affected the seaweed farming. Over half of those surveyed reported that such strong waves have carried away the plots causing detachments to the seaweed growing structures and floating debris entangled with the existing crop. For these reasons, the seaweed production within the studied area fluctuates throughout the year.

In case of severe damages, farmers have terminated seaweed cultivation prematurely. This finding has implications for developing strategies to lower the adverse effects of environmental changes on seaweed farming. To promptly adapt to such changes, establishing an early warning system of sudden environmental changes and improving the awareness on the link between seaweed growth and environmental conditions seem vital. Addi-

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tionally, Neish (2013) suggested shifting the cultivation sites and cultivating appropriate seaweed cultivars as strategies to keep up a much seaweed production during unfavorable environmental conditions. In a study on Philippine seaweed farming conducted by Hurtado (2013), it was recommended encouraging farmers to buy a crop insurance to cope with the associated risk, despite the cost incurred on it. As Krishnan and Narayanakumar (2013) pointed out, a weather damage relief from government, providing floating rafts to tsunami-affected Indian seaweed farmers can be more beneficial under adverse environmental impacts. However, further studies that consider account site-specific mitigation strategies will need to be undertaken.

The poor quality of existing planting materials was ranked next to unfavorable weather condition as a major constraint faced by the seaweed growers (Zamroni & Yamao, 2011). Farmers usually practice self-propagation of seaweed by using cuttings that were set aside from the previous harvest. This continuous application of long-established knowledge in seaweed propagation, in terms of utilizing the old seaweed stock, it might have created inferior strains over the years. A possible explanation for this might be that the self-propagation may affect the growth rate and quality of seaweed. A further decline in the existing seed stock makes it, so the farmers are unable to optimize the yield. Additionally, rather than practicing self-propagation as individual farmers, a specialized and collective seed production system would become more economically efficient by means of attaining the advantage of economies of scale. Thus, it can be suggested that establishing commercial seaweed nurseries, as previously described by Neish (2013) and Hurtado (2013) for respective Indonesian and Philippine seaweed industries, requires the creation of improved seaweed strains. However, the technological complexities attached to such a process will not enable farmers to start commercial nurseries. Therefore, the intervention of the government and other related parties is a determining factor in this regard.

Distortions prevailing in the existing seaweed purchasing mechanism or the contract growing system (Krishnan & Narayanakumar, 2013) that creates a pre-determined purchasing arrangement in between the buyer and the grower have discouraged the seaweed farmers. In this study, lower farm gate price (Zamroni & Yamao, 2011; Hurdato, 2013) that does not rise as the cost of living made the average price paid to the farmer stagnated at a lower level over the years. Therefore, the farmers feel that their efforts are not properly compensated. The dependence of the Sri Lankan seaweed industry entirely on overseas processors and non-existence of benchmarking international prices at the local seaweed market could be well responsible for this relatively lower farm gate price. The majority of respondents viewed that the buyers regularly justify these low prices, highlighting the importance of technical provisions, like raw materials and advisory support, which are mainly provided by them. As there are no other marketing channels available, the growers are forced to accept the price dictated by the available buyers. Generally, under a limited number of buyers, a monopsony situation or else oligopsonistic pricing (Hurdato, 2013) tends to occur, repressing the price paid to growers while weakening the bargaining power of the farmers. Approximately two-thirds of the participants commented that sporadic payment (Tobisson, 2013) and defective weighing were also distorted qualities of the existing purchasing system. Although the performance of the existing purchasing system is not ideal, the farmers still believe that the protection from price volatility occurred due to periodic disequilibrium in supply and demand. Additionally, the nonexistence of layers of intermediaries create a favorable environment to engage in the cultivation. This would appear to indicate that corrective actions on the identified limitations would turn the contract growing system more beneficial for the seaweed farmers.

Thanks to the increasing number of plots and farms, the near-shore areas that are generally accepted as ideal aquatic environments for seaweed cultivation are limited and subjected to competition. Therefore, in absence of rich farm locations, farmers have shifted the seaweed cultivation to less fertile aquatic environments. Among the causative factors behind this, the legal cut-offs imposed by the government in addressing special local conditions, like national security, conservation, and coastal management were prominent. Within the permitted area, seaweed-farming locations are co-managed by coastal villagers and a considerable proportion of the existing farms are represented by idling seaweed farms. Seaweed farmers, those who are willing to expand their cultivation by increasing the number of seaweed rafts, have undergone serious issues in managing these idling farms. Moreover, the plots that are abandoned for a long time create a dirty and more disorganized system. Very few participants of those surveyed (10%) indicated that depriving near-shore areas has added extra transportation cost and thereby the overall production cost escalated proportionately. This is hardly distinguishable from Zamroni and Yamao (2011), where the production costs of seaweed farms located at the deeper waters are much greater compared to those in shallow waters. Findings so far eventually lead to consider the reordering of existing seaweed farms supported by a proper spatial planning program, and the need to set up a more defined legal policy framework of marine farm tenure (Zamroni and Yamao, 2011). These policies could support the issue of licenses, especially when expanding across the country, to avoid social conflicts while maximizing productivity and identifying promising farm sites for further development of the seaweed cultivation.

The existing post-harvest processing of seaweed confines to purifying and drying them under sunshine to produce dried seaweed as a raw material for international processors. Apart from few respondents (15%), those who are utilizing at least bamboo racks for drying seaweed, dried seaweed on the sand. Consequently, during the rainy seasons, seaweed growers face difficulties in managing time for getting a quietly dried harvest. Additionally, the present drying technology does not support increasing production, particularly during extended rainy periods. It was revealed that the farmers and buyers equally do not consider much about the quality of dried seaweed. Therefore, quality standards for dried seaweed are not customary within the system. Currently, buyers pay a uniform price for dried seaweed regardless of quality. However, it would be beneficial for the market mechanism to motivate growers to consider the quality of seaweed by the reward of elevated prices. Another issue that emerges from these findings is lacking post-harvest processing or value-added products (Valderrama *et al*., 2013; Zamroni & Yamao, 2011). Commonly, value-added seaweed products receive a higher price in the international market compared to unrefined products that eventually results in low-profit margins. Therefore, it will bring in more entrepreneurial qualities to the growers if they could consider producing value-added seaweed products. This view is supported by Prado *et al*. (2012) who state that value-added initiatives are effortlessly achievable with available family labour, mainly more women, and female children. However, technical complications and desired capital inflows would be restrictive factors in this regard. This combination of findings suggests the need of establishing best practices (Rebours *et al*., 2014) and quality standards (Hurtado, 2013) by respective standard-setting agencies for dried seaweed. To facilitate investigating prospects for processing seaweed, more multidisciplinary research will be needed linking the affiliated research institutes (Abowei & Ezekkie, 2013).

It can be seen from the study that unlimited exposure to burning sun, wind, and saline water under poor working conditions cause occupational health hazards (Valderrama *et al*., 2013; Tobisson, 2013) similar to general fatigue, eye soreness, skin problems, and allergies. A common view amongst interviewees was that activities, like initial establishment and hauling harvest, demand physical stamina and are repeatedly causing musculoskeletal pains and aching backs. It is difficult to explain the consequence of such health hazards on the performance of seaweed farming, but it might be related to poor health conditions, which diminish the overall labour productivity.

Though fish grazing (Valderrama *et al*., 2013) has taken place within the study area, it is interesting to note that most of the respondents did not name it as a main constraint. There was a sense of invading certain areas by exotic fish species among the interviewees. However, farmers did not leave out fish threatening periods or alter the cultivation season in response to this problem. Issues related to disease outbreaks also were not particularly prominent within the study area.

Conclusions and recommendations

The study concludes that the present seaweed farming system in the Northern coastal part of Sri Lanka is reasonably profitable and generates considerable additional employment opportunities, thus finically profitable venture. The perceived importance of seaweed as a vital livelihood option proves that the system is socially acceptable among the coastal communities in Northern Sri Lanka. These findings disclose the distinct possibility of the venture to further improve as a commercial enterprise in order to harness its full potential. However, further investigations are needed to identify the biological sustainability of the system for recommending it for further replication to other coastal areas in Sri Lanka. Furthermore, there is a definite need for an open interaction between government, farmers, traders, and representatives of related sectors to further promote the seaweed farming as a commercial venture in coasts of Sri Lanka.

Conflict of Interests

The authors hereby declare that there are no conflicts of interests.

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Linking sustainable diets to the concept of food system sustainability

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Abstract

Based on insights from an ongoing research project on food sustainability, we argue that discussing sustainable diets in isolation from food systems poses risks. Among these risks are making healthy diets exclusive, or ignoring externalities like biodiversity loss, land concentration, and encroachment on commons. Case studies from Bolivia and Kenya show how marked shifts from traditional to more uniform diets rich in sugar, salt, and fatty acids come with a radical transformation of food systems. Systems formerly based on local knowledge, local inputs, and local labor relations become dependent on external inputs, heavy mechanization, and productive specialization. Making diets more sustainable requires policies that protect existing and strengthen new forms of family and community farming. We discuss critical links between sustainable diets and sustainable food systems with reference to five principles of food sustainability: food security, the right to food, reduction of poverty and inequality, environmental performance, and resilience. Our analysis provides a basis for more comprehensive research and policies that minimize trade-offs and maximize synergies between sustainable diets and food systems.

Introduction

Over the last decades, the world has seen a shift from diverse, traditional, and locally-based diets to more uniform, standardized, and place-independent modes of food consumption and production (La Trobe & Acott, 2000; Tilman & Clark, 2014; Traill, Mazzocchi, Shankar & Hallam, 2014). Nowadays, wealthy consumers worldwide have the possibility to purchase food from faraway places and to adjust their diets to personal preferences as well as to "mainstream" trends. This development was enabled by doubling international food trade since the 1980s (D'Odorico, Carr, Laio, Ridolfi & Vandoni, 2014), and it has had wide-ranging effects. On the production side, these effects include structural changes in many parts of the world (from agricultural societies towards service-based societies), a decreasing number of people working in food production, and a concentration of power along food value chains.

On the consumption side, the change in diets with increased consumption of sugar, salt, and fatty acids in processed food has led to an epidemic prevalence of obesity and related cardiovascular diseases in many parts of the world (Lifshitz & Lifshitz, 2014; Müller-Riemenschneider, Reinhold, Berghofer & Willich, 2008). Related health costs are rising (Allison, Zannolli & Narayan, 1999; Dee *et al*., 2014; Konnopka, Bodemann & Konig,

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2011), and due to its epidemic dimension, the problem is moving up on the political agendas of many states.
Different authors suggest various remedies for the problems that come with the shift in how we produce and consume food. While some studies address the production side and emphasize the importance of increasing food production (for a critical discussion see Godfray *et al*., 2010; Tomlinson, 2013), others focus on the consumption side and place individual diets at the center of the discussion (e.g., de Boer, Schösler & Aiking, 2014). We argue in this article that focusing on one side only means neglecting the problem's complexity, and therefore, it is crucial to take a comprehensive food systems approach (Ericksen, 2008). Such an approach should consider human health and environmental impacts as well as regulatory, trade, and rights-based aspects. There is a need for reflexive processes that consider the complexity of entire food systems.

Reflexive processes aiming at sustainability solutions involve various scientific and non-scientific actors and perspectives and have a strong normative component. They have the objective to produce not only systems knowledge (which often involves disciplinary modes of knowledge production) but also target knowledge (about the desired future state of a system) and transformation knowledge (on how to arrive at this desired state) (Hirsch Hadorn, Bradley, Pohl, Rist & Wiesmann, 2006). Accordingly, such processes usually include various forms of inter- and transdisciplinary research (Pohl & Hirsch Hadorn, 2007).

In this contribution, we propose to integrate the discussion on sustainable diets into the concept of food system sustainability. We discuss the links between the two in light of the findings of a transdisciplinary research project aimed at assessing the sustainability of different food systems in Bolivia and Kenya and at implementing interventions for increasing that sustainability. Both countries are affected by hunger and food insecurity while legislation on the right to food is well advanced. Therefore, our discussion will focus prominently on the realization of the right to food, based on examples from the project's case studies.

In the following sections, we give an overview of existing literature on problems of today's global food system; introduce the transdisciplinary approach applied in our project; and, present and discuss some of our findings from three years of research by highlighting the links between dietary aspects and overall food system sustainability.

Today's global food system in the literature: An overview

The globalization of diets and its impacts on food systems

The massive changes in food production and consumption have led to an increasing disconnect between food producers and food consumers (Boehlje, 1999). Many consumers have grown used to finding a similar standardized food offer around the world. This can be seen as a globalization of diets. While this development is much more advanced in industrialized countries, it is increasingly affecting people in developing countries as well (Reardon, 2015). The extension of markets and the related increase in potential customers promise income and business opportunities, but intensified food production practices also pose risks of adverse environmental and societal impacts (Tilman, Cassman, Matson, Naylor & Polasky, 2002). Such risks include high levels of pesticide and fertilizer use, which cause pollution and degradation of water and soils (Carpenter *et al*., 1998; Matson, Parton, Power & Swift, 1997; Novotny, 1999); advancing agricultural frontiers, which destroy forests and other natural habitats (Morton *et al*., 2006; Richards, 2015); monoculture; and the increasing replacement of diverse agricultural crops with few hybrid and genetically modified varieties, leading to biodiversity loss (Altieri, 2005; Fahrig *et al*., 2015).

Furthermore, there are socio-economic impacts on people's living conditions. Such changes include increased dependency on one or few goods for export (La Trobe & Acott, 2000); substantial changes in land use and the related social contexts (Fearnside, 2001); progressive concentration of land in the hands of fewer people, often linked with a shift from food production for local consumption to other uses, such as production of food for export or agrofuels (Oliveira, McKay & Plank, 2017); and a tendency of healthy and varied diets becoming less affordable for people with low buying power.

There is evidence that efforts to increase agricultural productivity by means of sustainable intensification does not, as a general rule, reduce the need for new land, but instead fuels expansion of the agricultural frontier (Ceddia, Bardsley, Gomez-y-Paloma & Sedlacek, 2014). The described adverse impacts of the increasing globalization of diets on food systems are fueled by a productivist paradigm which implies that feeding a growing world population will only be possible by spreading intensified agricultural practices, advancing biotechnology, and massively increasing food production (Fouilleux, Bricas & Alpha, 2017). However, there is no scientific ba-

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Table 1: Different frameworks for sustainable diets

Authors	Addressed dimensions	Objective of framework
Downs, Payne, & Fanzo, 2017	Socio-cultural and political Markets, trade and value chains Environment and ecosystems Food security and agriculture Nutrition and health	Assessment of individual policies in terms of sustain-ability
Mason & Lang 2017	Health Environment Culture and society Quality Economy Policy and governance	Addressing diets in a com-prehensive way
Von Koerber, Bader, & Leitzmann, 2016	Health Society Environment Economy Culture	Definition of sustainable diets

sis for this predominant focus on increasing production. Indeed, we are already producing enough food to feed the projected population in 2050 (Moore Lappé, 2013). The total of food calories produced in 2015 amounted to over 2800 kcal per capita per day (FAO, 2015). Another study even mentions 4600 kcal per capita per day, but notes that fairly large shares are wasted during production (~13%) and consumption (~20% at household level in wealthier countries) (IPES, 2016).

From sustainable diets to sustainable food systems

Different measures to address the health implications of changed diets have been discussed (Kersh, 2009; Reisch, Sunstein & Gwozdz, 2017; Ries, Rachul & Caulfield, 2011), and governments have started to think more about how to influence people's diets. Several authors have assessed the effectiveness of various proposed methods to do this, including taxation and subsidies, the regulation of ingredients used in the processing industries, and prominent labelling of packaged food as healthy and unhealthy (Lobstein & Davies, 2009; Loughnane & Murphy, 2015; Lustig, Schmidt & Brindis, 2012; Mytton, Eyles & Ogilvie, 2014; Ni Mhurchu ., 2015; Niebylski, Redburn, Duhaney & Campbell, 2015). Health issues caused by globalized diets are increasing. At the same time, the problem of malnutrition in many parts of the world remains unsolved, with an estimated 800 million people still suffering from hunger, and an even higher number from nutrient deficiencies (Ingram, 2017).

In conclusion, diets and nutrition deserve special attention for two main reasons: First, because they form the basis for an active and healthy life, and second, because they fail to do so for a large share of the world population. However, diets have substantial implications for entire food systems. In order to avoid spreading environmental and societal problems, efforts to improve diets must generally consider sustainability concerns. We therefore argue that the paradigm of "healthy diets" should be rephrased to "sustainable diets" and related to the concept of food system sustainability, with the aim of eventually finding appropriate measures to promote and support sustainable diets within sustainable food systems.

There are three aspects which require consideration when defining sustainable diets. First, sustainable diets are a question of receiving the required macro- and micronutrients to sustain an active and healthy lifestyle (McCalla, 1999). Second, the consumed food should come from sustainable production systems. This implies that production and processing activities should meet social, environmental, and economic sustainability criteria. Third, when we ask what food is adequate, we are dealing primarily with a normative question that reflects social and cultural backgrounds (Anderson, 2005).

Several authors have made suggestions for integrative approaches to sustainable diets by including different dimensions (e.g., Downs, Payne & Fanzo, 2017; Mason & Lang, 2017; von Koerber, Bader & Leitzmann, 2016). Table 1 summarizes the aims and dimensions addressed by the proposed frameworks.

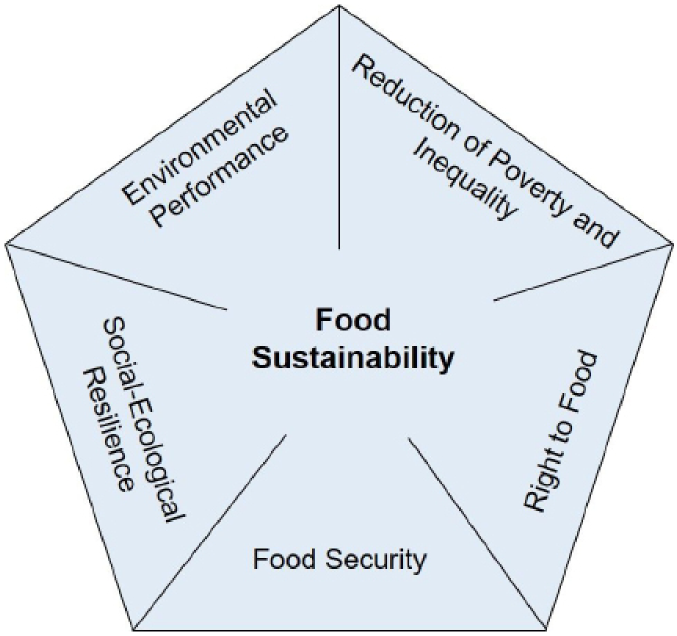

Figure 1: The five dimensions of food sustainability (Source: Rist *et al*. 2016)

All three studies place diets at the center of the discussion while simultaneously considering value chains. We argue, however, that diets need to be integrated into a more comprehensive food systems approach in order to capture the complexity of these problems. Food systems include not only value chains but also the natural resource base, the political context, and flows of information and services. Moreover, food systems encompass many interlinkages at and between different scales from local to global. They connect activities in distant places. This poses challenges when analyzing them as well as when trying to advance them towards greater sustainability. Our food sustainability framework focuses on entire food systems and is constructed as an intervention tool to analyze food system weaknesses and find ways of increasing the sustainability of these systems. Sustainable diets are an integral part of food systems, therefore, we treat them as such when discussing their interrelations.

Our understanding of food sustainability has several foundations. One is the concept of food systems, comprising all activities along the food value chain, from production – including the required resources and inputs – through transport, trade, processing, and retailing to the consumption of food. Furthermore, a sustainability assessment of food systems must also include their links to food system drivers, such as changes in the natural environment and the social context, as well as to food system outcomes in terms of their availability, accessibility, utilization, and the possibilities they offer to achieve prosperity (Ericksen, 2008). A second point is that food system sustainability includes human rights, in particular the right to food, which, though not legally binding, entails the obligation of states to support this right with the means they have at their disposal (De Schutter, 2014). A third important part of food system sustainability is that the food system should contribute to more equitable conditions and improved livelihoods for actors involved (Christiaensen, Demery & Kuhl, 2011; Ribot & Peluso, 2003). This part is often addressed by discussing properties of value chains, such as their structure (Taylor, 2005), their governance (Gereffi, Humphrey & Sturgeon, 2005), and their impact on poverty reduction and inequality (Stoian, Donovan, Fisk & Muldoon, 2012). Finally, food system sustainability means protecting environmental goods and services and increasing resilience within food systems (Aubin, 2013; Berkes, Colding & Folke, 2003).

In an ongoing, transdisciplinary research project called "Towards Food Sustainability: Reshaping the Coexistence of different Food Systems in South America and Africa", we have based our definition of food sustainability on five dimensions (Figure 1): food security, the right to food and other related human rights, reduction of poverty and inequality, environmental performance, and social-ecological resilience (Rist *et al*., 2016).

Making food systems more sustainable: a transdisciplinary approach

How do we move from this theoretical concept of food sustainability to an actual improvement in the sustainability of food systems and diets within these systems? Improving the sustainability of food systems is an explicit goal of our research project. Besides an assessment of the current sustainability of a given food system, this requires collaborative reflection and implementation of

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innovation strategies and policy options that introduce and support the proposed changes. We define innovation strategies and policy options as changes to the current food system that may be initiated by public administrations, civil-society actors, and private initiatives that do not a priori involve changes to the legal framework. However, they might lead to such changes in due course. When searching for policies that can support sustainable development of food systems, it is necessary to examine existing power structures and the ways in which they perpetuate unsustainable activities within the system. Such activities include, for instance, pressure on smallholders from international competition and subsidies in developed countries, or dependencies on multinational companies and international trade (Lapatina & Ploeger, 2013). These structures and mechanisms need to be considered when aiming to improve current food systems.
The explicitly normative and contested nature of interventions in food systems necessitates a transdisciplinary approach that involves scientific as well as non-scientific actors in the knowledge production process (Bouma, van Altvorst, Eweg, Smeets & van Latesteijn, 2011; Dentoni & Bitzer, 2015; Lang *et al*., 2012). Our research project addresses all three forms of knowledge presented in the introduction: systems, target, and transformation knowledge. The food sustainability concept with its five dimensions represents target knowledge, that is, normative knowledge on desirable development pathways. Empirical assessment of food systems creates systems knowledge from different disciplinary perspectives. Innovation strategies and policy options defined in a multi-stakeholder transdisciplinary process represent transformation knowledge, that is, knowledge on how to achieve the desired developments.

A transdisciplinary approach to research supports the production of knowledge that is based on compromises between actors' different interests and expectations, addresses key questions asked by the actors involved, and is implementable in real-world situations. Thus, it is likely to produce salient, credible, and legitimate results (Chaudhury, Vervoort, Kristjanson, Ericksen & Ainslie, 2013). Furthermore, a transdisciplinary approach can give a voice to actors who might otherwise have difficulties to make themselves heard. A transdisciplinary approach is particularly appropriate for finding effective innovation strategies and policy options and for accompanying their implementation towards the proposed changes in food systems and diets (Ernesto Méndez, Bacon & Cohen, 2013). Transdisciplinary research processes profit above all from the diversity of participating actor groups. In the case of our research project, these include academic and non-academic specialists and other food system actors in the five key dimensions of food sustainability.

Our project applied a transdisciplinary research process (Rist *et al*., 2016). This consisted of the following steps: (1) sustainability assessment of a specific food system according to a previously developed set of indicators; (2) identification, together with a group of scientific and non-scientific experts as well as other food system actors, of possible innovation strategies and policy options for improving the food system's sustainability; and, (3)

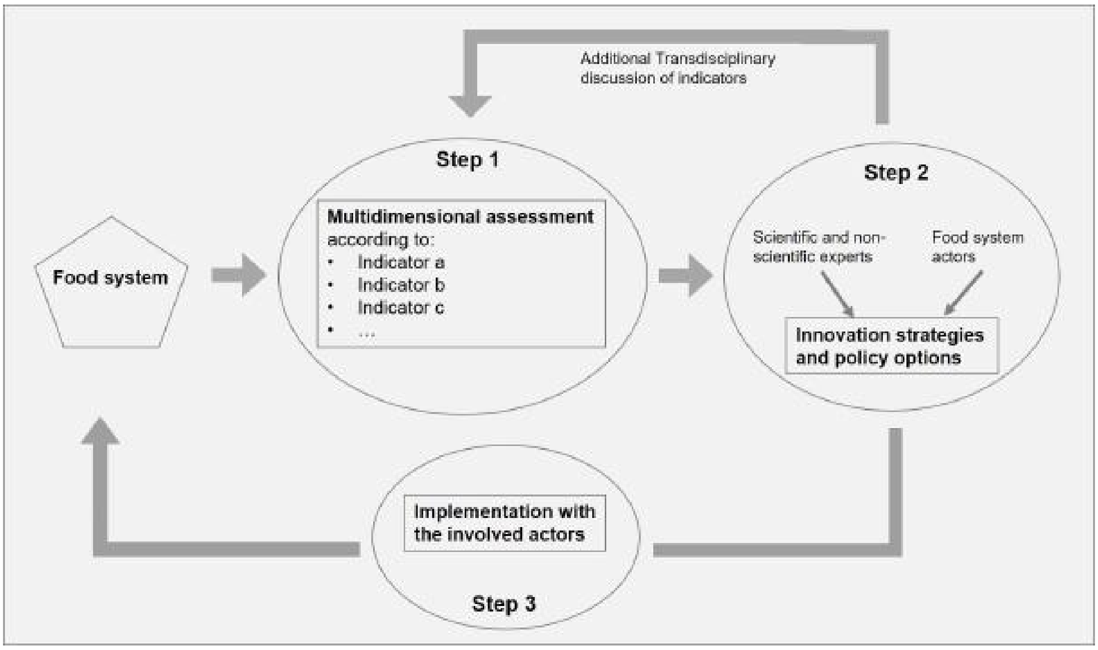

Figure 2: Procedure of food system assessment and improvement (Authors' illustration)

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implementation of the proposed interventions in close collaboration with and under the supervision of the same group (Figure 2).

Each of these steps is transdisciplinary in nature. Transdisciplinary co-production of knowledge in step (1) occurs mainly in the form of networking and soliciting of advice from involved actors. In contrast, steps (2) and (3) comprise the use of explicitly transdisciplinary methods to identify feasible innovation strategies and policy options for the specific food system and to then implement them together with the actors. The most prominent of these methods is participatory workshops that engage actors in solution-oriented discussions with policymakers (Salter, Robinson & Wiek, 2010).

When exploring ways to improve the sustainability of diets within the food systems that our project focuses on, we look at diets as an integral part of food systems. Consequently, we discuss measures that specifically target the dietary context within those systems. The following section provides more detailed insight into this dietary context.

Sustainable diets and food system sustainability: key insights from three years of research

In the case studies, we used the above-mentioned steps to achieve greater sustainability in food systems and diets. The thorough assessment of a food system along the five dimensions of food sustainability in the first step led to a ranking of the system on an ordinal scale between 0 and 4. Data were collected for 11 to 30 indicators in each of the dimensions. With respect to diets, the indicators included consumers' perceptions regarding health impacts of different types of food, the source of their food, and what they considered to be "good food", among others. Data on the indicators were collected over two and a half years of interdisciplinary research within different master's-level, doctoral, and post-doctoral studies for each of the five dimensions of food sustainability in different food systems in Bolivia and Kenya. Data collection methods depended on the research questions, and included structured and semi-structured interviews, surveys, focus groups, observation, participant observation, life cycle inventory assessments, 24-hour dietary recall, and participatory mapping.

In the third year of research, we began to hold data synthesis workshops to integrate knowledge from individual projects and to agree on the most relevant indicators for each dimension, following detailed discussions among all involved researchers. The results of this assessment point to problems in the food system that were addressed in the second step of the transdisciplinary process, where the aim was to identify innovation strategies and policy options. In the currently ongoing second and third steps of the process, discussions with different groups of scientific and non-scientific actors are leading the way from initial ideas to actual interventions that are feasible in terms of their goals, realistic in relation to the available personnel and material resources and supported by the involved governmental and administrative units in the food system. It is advantageous to include national and international policy experts in the process in order to profit from their expertise and to refine interventions and ensure their applicability in the specific food systems' context. Once specific and agreed intervention proposals are on the table, actions for implementation can start, with support from researchers and in close collaboration with the involved group of actors.

First stakeholder workshops in Bolivia and Kenya showed that food system sustainability could be improved with seemingly small interventions, such as providing a marketplace for agroecological produce that is protected from rainfall or investing in rainwater harvesting to improve water availability during the dry seasons. Other proposed interventions require more effort, commitment, and time of all actors involved. Examples include water and irrigation forums aimed at achieving a more equitable and fair distribution of available water resources among the different food systems, and governmental support for suitable soil improvements.

The applied set of indicators also provided information about the dietary habits of actors in the assessed food systems. These included the availability of food in the system, its acceptance by consumers, its diversity, and its safety. We therefore suggest that a food system assessment includes a dietary assessment and enables reflection on innovation strategies and policy options that improve the sustainability of consumers' diets. In order to highlight possible ways of promoting diets that are sustainable in terms of overall food system sustainability, in the following sections we discuss examples from our research project of existing measures that increase food system sustainability in each of the five dimensions, underlining their relevance to diets. For each of the examples, we suggest ways of further increasing the given food system's sustainability. Linking the five dimensions of food sustainability to the debate on sustainable diets means looking for measures that support sustainable food consumption. These are instruments that encourage a certain behavior among consumers who have a

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choice or support poorer parts of the population in accessing better and more sustainable food (Pretty, Morison & Hine, 2003; Reisch, 2013).

The right to food

The right to food refers to General Comment No. 12 of the United Nations Committee on Economic, Social and Cultural Rights, which affirms that every person living in a state has the right to adequate food at any time and that its availability must be ensured now and for future generations. The right to food must not be restricted or inhibited by anyone, and states have the obligation to fulfil it where it is not given (CESCR, 1999; De Schutter, 2014).

Regarding the right to food, Bolivia offers an interesting example of a measure to improve food system sustainability, namely a governmental initiative that offers subsidized school meals to schoolchildren (Bolivia, 2015; Gonzales, 2016). These meals must be sourced from local small-scale farmers and small enterprises, and must consist of nutritious ingredients and local varieties, for example of banana or amaranth (which is not yet always the case). Bolivia is thus making an effort to fulfil its obligations (as stated by the UN in terms of the right to food) to provide adequate food (food that fulfils dietary as well as cultural requirements) to all schoolchildren. By doing so, it is potentially improving the nutritional situation of vulnerable people.

The sustainability aspect (adequate food must be available now and for future generations) of this example is illustrative, because beyond providing food for schoolchildren, this governmental initiative supports local supply chains and provides a fair and stable income for small-scale producers without distorting prices. In addition, it provides monetary relief for parents in vulnerable population groups.

This governmental initiative could be further improved through policies specifying environmental requirements for production of the sourced food. At present, such policies are lacking; consequently, some of the food is produced with heavy inputs of pesticides, the health impacts of which on both producers of the food and on the children who consume it are not monitored. In a second step, the government could extend this initiative to other canteens that it maintains, such as in police stations or hospitals. The benefits of sustainable public procurement have also been highlighted by other authors and represent an effective way of supporting certain production standards (Oruezabala & Rico, 2012; Preuss, 2009; Walker, Miemczyk, Johnsen & Spencer, 2012).

Food security

Our definition of food security follows McCalla (1999) and includes the availability of food supplies, access to these supplies, adequate utilization of food in nutritional terms, and stability of these three aspects over time. Another example from Bolivia shows how the dimension of food security can be addressed through non-monetary food subsidies that are targeted specifically at pregnant women and newborns. Niebylski *et al*. (2015) confirm that food subsidies can contribute to making diets healthier.

It is widely acknowledged that the first 1000 days, from conception to completion of a child's second year living, present a window of opportunity for healthy development of a child in general, especially development of the brain, if the child receives adequate nutrition (IFPRI, 2015). In our example, women receive food subsidies in the form of food packages during six months of pregnancy and the first year after birth. The packages contain nourishing food, such as milk, amaranth products, and honey. Compared to the example described with regard to the right to food, this example addressing food security is a measure that specifically targets the fairly short window of opportunity in which children can be provided with the necessary nutrition to support a healthy development.

The contents of these packages must be produced locally (although this is not yet always the case), similar to the previous example of locally procured school meals. However, there are no environmental requirements for their production. More research into the sustainability of the supply chains of these packages would be needed to assess in detail how environmental standards could be improved.

Reduction of poverty and inequality

With respect to reduction of poverty and inequality, it is important to consider what financial means people have at the end of the month and how access to resources is distributed. An example from a large, industrial, export-oriented food system in the Mount Kenya region shows how private food subsidies can increase the financial means of agricultural workers. These workers belong to the more vulnerable parts of the population due to their low income.

In this example, a company that produces vegetables for export to a European market offers its workers subsidized meals for lunch and dinner, depending on their working shift. The cost of these meals is 10 Kenyan Shillings (~ one Euro Cent), which is very cheap by Kenyan standards. The total cost of meals is deducted from the workers' salaries at the end of each month. The meals consist of ingredients that cover necessary nutrients, such as carbohydrates, fibers, proteins, and vegetables, but workers have complained about lack of variety in the menu, the size of portions, and the quality of ingredients as the canteen uses leftovers from sold vegetables.

In terms of poverty reduction, the subsidized meals provide necessary nutrients and help the workers save money. However, this company initiative performs poorly in terms of inequality, as managers and supervisors already earn more by comparison with workers. Moreover, they are not charged for their meals although they could more easily afford them. This unequal treatment provokes resentment among workers.

In terms of reducing inequality, this measure could be improved by introducing equal or income-related subsidies for all employees. This would mean only a small change for managers and supervisors, but it would constitute an important signal towards workers. Such signals should not be underestimated, as perceived inequality plays an important role in generating inequality in general (Reygadas, 2015).

Use of leftovers from the company's own production can benefit sustainability if these leftovers are good food that would otherwise be composted or, even worse, brought to a landfill. However, this should be explained and discussed with the employees, who currently consider the food to be of substandard quality. More appreciation for this procedure could be generated by involving workers in the selection and preparation of food and assuring them that they are not being served low-quality food.

Environmental performance

Environmental performance in our project comprises several aspects, such as the total amount of land, energy, and water required for food production (according to Gerbens-Leenes, Moll & Schoot Uiterkamp, 2003); the use of seeds, fertilizers, and pesticides (Altieri, 2009); the use of other material inputs, human influence on landscapes and biodiversity (Peterseil *et al*., 2004); and key actors' perceptions regarding the food system's influence on degradation, including health risks and conservation.

When it comes to addressing environmental performance via diets, we see that transport has a substantial impact on the environment in food systems both in Bolivia and in Kenya. The impact increases if transport of inputs is included in the assessment. This is in line with other studies, such as Foster *et al*. (2006) and Sim, Barry, Clift & Cowell (2006). Hence, diets that are beneficial for the environmental performance of a food system should ideally include local produce grown with low inputs, diverse crops, and fresh fruits and vegetables. These requirements are generally compatible with the composition of traditional diets in both our research countries, where people traditionally consume a variety of local staples, diverse fruits and vegetables, and high quantities of legumes but low quantities of meat and dairy products. These diets are associated with site-adapted agricultural production, crop diversity, and low environmental impacts. The advantages of this type of production have been discussed in several contributions to this journal (Ciccarese & Silli, 2016; Kanaani, 2016; Reiter, Huson & Gonzalez, 2014).

We also see that knowledge about traditional crops and the preparation of meals from them is still present among the older generation but is fading away among younger people (Hertkorn, 2017). This gradual disappearance of knowledge concerns not only the preparation of traditional food but also the production of traditional crops. This is causing a decrease in crop variety, and thus indirectly increases producers' vulnerability and reduces the consumed crops' nutritional value (Gruber, 2017). While other studies do not use the term "traditional food", they are likewise interested in the relationship between "good" or "nutritious" food and sustainable food. For example, Dixon and Isaacs (2013) find that fresh and local produce is viewed as one of the main components of such food among disadvantaged population groups in Western Sidney, Australia, while Van Loo *et al*. (2017) find good associations between healthy and sustainable diets.

One way to push such diets would be to support agroecological producers in building networks and developing local markets. Participatory guarantee systems represent such an example. They help local producers who supply local markets to mutually certify their fair, local, and environmentally friendly products as fulfilling high sustainability requirements, without having to face the high hurdle of obtaining international organic and fair trade certification (Home, Bouagnimbeck, Ugas, Arbenz & Stolze, 2017). Nonetheless, participatory guarantee systems serve to assure local consumers that they are buying high-quality, diverse, local, and accessible food.

Resilience

The fifth dimension of our food sustainability concept is resilience. Resilience refers to being able to cope with and

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adapt to both change and pressure on the social-ecological system (Jacobi *et al*., 2018, Berkes *et al*., 2003), specifically on the food system (Tendall *et al*., 2015). In that sense, special attention is given to food systems' buffer capacity (the ability of a food system to cushion stress and shocks), self-organization (social organization of food system actors, ecological self-regulation, and functional interaction of food system processes), and capacity for learning and adaptation (the capacity to learn from past events and to develop existing contexts further) (Carpenter, Walker, Anderies & Abel, 2001).

A high percentage of people's food consumption in rural areas worldwide depends directly on their own food production, and smallholders are responsible for a majority of global food provision (Tscharntke *et al*., 2012). Smallholders produce and thus preserve an immense diversity of crops and breeds (~1.9 million crop varieties) (Nicholls & Altieri, 2018), whereas industrial food production relies on a comparably small number of commodity crops and terrestrial breeds. In terms of resilience and sustainable diets, a high crop and breed diversity in food production, on markets, and on plates is clearly preferable to industrial monotony. A good mix of cash crops and highly diverse food production is also discussed by other authors as a way of increasing resilience (Cadena, Pond & Rattanasorn, 2014).

An example of resilience-building in Kenya highlights the creativity of an individual farmer who was faced with continuous droughts and built a highly sophisticated water harvesting, water storage, and drip irrigation system on his farm. The system enables him to save enough water during the rainy season to bridge the increasingly long months of drought. As a consequence, he is now able to irrigate his fields at times when other farmers lose their entire yields. The system guarantees the farmer's food security during droughts and ensures that he can continue to sell his produce on the market, thus serving his own and other peoples' dietary needs. In addition, his success has attracted the interest of other farmers in his neighborhood. He now helps other farmers to install such water harvesting, storage, and irrigation systems on their farms. This example shows how individual initiatives can improve resilience in a food system from the bottom up.

In order to increase the impact of such initiatives, the government could scale them up by providing targeted support to innovative farmers. In addition, it could support the creation of local farmer networks that would help to increase the bargaining power of frequently isolated individual farmers.

Conclusion : Minimizing trade-offs, maximizing synergies

The diverse problems that come with the current global food system are complex and interrelated. Accordingly, they need to be addressed through approaches that are capable of grasping this complexity. Therefore, in this contribution, we argue that it is necessary to integrate the debate on sustainable diets into discussions on food security, and into a more holistic food systems approach to improve human health and well-being, while avoiding adverse environmental impacts.

Based on the results of an ongoing transdisciplinary research project, we discuss measures that can help to support sustainable diets within in the framework of food sustainability. Examples from case studies in Bolivia and Kenya demonstrate how public food subsidies can be effective measures to implement the right to food and reduce food insecurity for more vulnerable groups of people. In addition, subsidies in the form of meals offered by local private companies can help to alleviate poverty. By contrast, the reduction of inequality is not just a question of resource distribution and access to resources but also a question of perception and how people see themselves in relation to others. Environmental performance is best supported by consuming fresh food from local production with low external inputs and a high crop diversity, which corresponds well with traditional diets in many places around the world. Last but not least, resilience can be increased by supporting people in organizing themselves within networks and developing their creative potential.

When designing interventions to improve the sustainability of food systems, disagreements and conflicts are inevitable due to the different actors' diverse objectives and strategies. Improving the sustainability of interconnected food systems requires observing and critically reflecting on potential trade-offs. Achieving agreement and consensus might not always be possible, but a transdisciplinary research process, which involves academic and non-academic experts and other actors, can help to assess how the diverging options prioritized by different actors play out in terms of sustainable diets. On the other hand, the implementation of interventions for more sustainability in food systems can also benefit from synergies between different objectives. Our framework helps to anticipate and actively support them where possible.

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Conflict of Interests

The author hereby declares that there are no conflicts of interests.

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Research Paper

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Use of *aquagel-Polymer* as a soil conditioner for celery plants grown in sand culture

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Celery; Soil conditioner; Evapotranspiration; Plant tissue analysis; Drip irrigation; Soil amendments

Abstract

Celery plants were grown in ten liter black plastic containers filled with sand substrate then mixed with three levels of aqua gel-polymer. Three levels of irrigation water were applied by using drip irrigation for each aquagel-polymer treatment. The experiment was carried out at the Protected Cultivation Experimental Farm in Dokki, Giza, Egypt to determine celery growth and yield under different studied treatments. Various levels of aquagel-polymer as well as irrigation water levels were applied in a factorial design with three replicates. Plant samples were collected six weeks after transplanting in order to analyze nutrient concentration. The results showed that plant height, number of leaves per plant, and dry weight were increased with rising irrigation water levels. The smallest celery yields were obtained in the lowest irrigation level at 50%. Control treatment (without aquagel-polymer) gave the lowest vegetative characters and yield during the two seasons. During both studied seasons, the highest vegetative characters and yields were obtained by applying 100% irrigation level combined with 2% of aquagel-polymer, followed by 100% irrigation level combined with 1% of gel-polymer. Water Use Efficiency (WUE) decreased with increasing irrigation levels. Meanwhile, using 2% of aquagel-polymer gave the highest WUE during both seasons. The plant analysis revealed that using aquagel-polymer led to an increase of nutrient content in celery leaf compared to the control treatment.

Introduction

Celery (*Apium graveolens L.*) is a biennial plant of the Apiaceae family. It is frequently used as a vegetable, spice, and traditional medicine in Egypt. Leaves and stalks (petioles) of celery are often used in salads and the seeds are used for the treatment of various diseases, including high blood pressure and muscular spasms (Helaly *et al*., 2014). In recent years, some problems in conventional soil practices caused the expansion of soiless culture, such as salinity and unsuitable soil characteristics, as well as limitation of available water resources in many countries. Replacing soilless growing systems with soil for plant growth, especially for vegetables such as cucumber, pepper, and tomatoes, can regulate plant nutrition and eliminate soil-borne diseases (Olympios, 1995).

Irrigation water is gradually becoming scare not only in arid and semi-arid regions but also in countries where rainfall is abundant. Therefore, water saving and conservation in Egypt is now essential to support agricultural strategy for efficient use of water by irrigation (Farag *et al*., 2015). Crop irrigation and water usage depend on factors, such as climate, soil properties, and soil moisture availability. Therefore, using proper soil conditioners during growth season improves water-holding capacity, water conservation and efficiency (Shahrokhian *et al*., 2013). Water Use Efficiency (WUE) can be increased by growing crops in soils enhanced with water-holding amendments like gel-polymers (Sibomana *et al*., 2013).
Gel-polymers are becoming progressively more important in regions where water availability is insufficient. The

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Table 1: Some Physical Properties of Sandy Soil with and without Application of Aquagel-polymer

	Physical properties			
Substrate	Bulk density (Kg/l)	Total porosity (%)	Water holding capacity (%)	Air porosity (%)
Sand 100%	1.86	29	20	9
Sand+ 1% polymer	1.84	58	50	8
Sand+ 2% polymer	1.80	80	66	14

aquagel-polymer can absorb water up to ten folds more than its own weight. When a aquagel-polymer is applied to poor agricultural soil, it can absorb and retain water, dissolve nutrients, and release them when required by the plant (Olanike & Madramootoo, 2014). Researchers have widely used gel-polymers as additives to potting media to increase WUE and improve water-holding capacity (El-Dolify *et al*., 2016). On the other hand, Tripepi *et al*. (1991) showed that the addition of an aquagel-polymer into the growing medium had little effect on container production of birch. They also mentioned that gel-polymers held higher amounts of moisture than a medium without gel-polymers. However, the moisture was retained by the expanded aquagel-polymer rather than being available for plant uptake. Other researchers, among them Farag *et al*. (2015), observed that using rice straw as a cultivated media is useful for encouraging vegetative growth.

Austin and Bondari (1992) reported that mixing the soilless media with a aquagel-polymer was detrimental to plant survival. Deghen *et al*. (1994) demonstrated that growth responses to aquagel-polymer varied between plant species and the number of applied irrigations. Furthermore, several studies have shown gel-polymers to increase germination and establishment of plants. For example, Maboko *et al*. (2006) found that aquagel-polymer increased the productivity of tomato on sandy soil. Studies on the incorporation of gel-polymers in a poor soil resulted in improved nutrient uptake by plants and reduced nutrient losses by leaching. The aim of this investigation was to study the effect of polymer levels, irrigation levels, and their combinations on vegetative growth, yield and WUE of celery grown under sandy culture.

Materials and Methods

This study was carried out on the experimental farm of the Central Laboratory for Agricultural Climate (CLAC), Agriculture Research Center (ARC) in Egypt over two successive winter seasons 2015-2017.

Plant material:

Celery (Apium graveolens var. rapeceum F1 hybrid) was used in this study. The seeds of this cultivar were obtained from Takii and Co. LTD (Kyoto, Japan). Seedlings were transplanted into the substrate system on 20, 22 November 2015 and 2016, respectively. The celery was harvested in the first week of March during the two seasons.

The following measurements were performed for five labeled-plants per replication for each treatment at the end of each growing season. Plant length (cm), number of leaves per plant, fresh and dry weight per plant, base plant diameter (cm) as well as celery yield were recorded.

Substrate system:

Pure sand was used in this experiment. Sand was washed with diluted hydrochloric acid (0.1 Mol/l) to remove all nutrient elements and then wash with tap water. Three different rates of aquagel-polymer (without, 1 and 2% by volume) were mixed with a sand substrate. The aquagel-polymer was sourced from the governmental manufactory belonging to the Governmental Egyptian Protected Agricultural Sector of the Ministry of Agriculture. The main component of aquagel-polymer is polycyclic acid (bulk density (kg/l) = 0.74, total porosity = 60.9 times/volume and the water hold capacity = 60.3 times/volume or 75 times/weight). The top five centimeters of the growing media was covered by pure sand in all of the treatments. Table 1 shows some physical characteristics

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of the sand mixtures with aquagel-polymer. Substrate physical properties were estimated according to Wilson (1983) and Raul (1996). Vertical black plastic pots (30 cm) were filled with 10 liters of the substrate mixtures. Pots were cylinder shape with a diameter of 30 cm; the height of the pots was 20 cm; and, the height of the media in the pots was 15 cm. The pots were arranged over 3 rows. The distance between every two rows was 0.6 cm. The distance between each two plants was 0.3 m. One plant was cultivated in each pot. Each experimental plot had 15 plants. The experiment was conducted in the open field conditions.

Irrigation treatments:

The current study used three levels of irrigation requirements (100%, 75% and 50%), which were calculated according to FAO 56 (Allen *et al*., 1998). A saubmersible pump (110 watt), as well as water tanks 120 L, were used in an open system of substrate culture. Plants were irrigated with drippers of two liters per hour capacity. The fertigation was programmed to work 4 times per day and the duration of irrigation time depended upon the season. The average irrigation time was between 2 to 10 minutes for each irrigation event. The emission uniformity of the drippers was measured with a value of 95%. The irrigation requirements were applied with a digital timer for each treatment to give the accurate irrigation water quantity for each irrigation treatment. Tables 2 and 3 illustrate the climatic data and irrigation requirement for 100% irrigation level. The quantities of Irrigation Water Requirement (IR) were derived from the 100% irrigation level. The climatic data were collected from an automated weather station allocated in the Dokki location (coordinates N 30.05 and E 31.20). IR was calculated according to FAO Irrigation and Drainage Paper 56 (Allen *et al*., 1998) as described by the equation:

$$IR = (ETo * Kc) * (1 + LR) * area / Ea \quad \ldots\ldots\ldots \quad (Liter / plant/ day)$$

Where: -

IR = Irrigation requirement for celery crop liter / plant/ day

Kc = Crop coefficient [dimensionless].

ETo = Reference crop evapotranspiration [mm/day].

LR = Leaching requirement LR (%) (assumed 20% of the total applied water).

Ea = The efficiency of the irrigation system, (assumed 85% of the total applied water).

Area = Plant area (distance between plants x distance between rows)

The WUE was calculated according to Steduto *et al*. (2012) as follows: The ratio of crop yield (Y) to the total amount of irrigation water used in the field for the growth season (IR), WUE (kg m3) = Y (kg)/IR (m3).

The WUE was calculated according to Steduto *et al*. (2012) as follows: The ratio of crop yield (Y) to the total amount of irrigation water used in the field for the growth season (IR), WUE (kg m3) = Y (kg)/IR (m3).

Plant analysis:

After six weeks, plant samples (outer leaves) were collected from transplanting and dried in the oven at 70°C for one day. Total N in the dried leaves, digested by H_2SO_4/H_2O_2 mixture, was determined using Kjeldahl method; total P was determined using Spectrophotometer (Model 6305); and, total K in leaves was determined using Flame photometer (Model PFP7). The chemical analysis of NPK was analyzed according to Hormitz (2000).

Experimental design:

A factorial design with three replications was used. Two factors were observed with irrigation water levels as the first factor, and applied polymer treatments as the second factor. Both factors were randomly distributed. Data were statistically analyzed using the statistical analysis system (SAS) program (SAS, 2000). The means that were significant were separated using Duncan's New Multiple Range Test at $P \leq 0.05$.

Results and Discussion

Plant growth characteristics and yield

Regarding the irrigation water treatments, 100% of IR produced the significant highest plant height, number of leaves per plant and plant dry weight. The 75% of irrigation water level was second, while 50% of irrigation water level produced the lowest vegetative characters (Table 4). Data in Table 4 shows the celery yield during both seasons. There were significant differences among tested treatments. The 100% of irrigation level gave the highest celery yield (fresh weight) during both seasons followed by 75% irrigation level treatment, while the lowest values were obtained by 50% of irrigation level.

The achieved results in Table 4 reveal that the aquagel-polymer treatments significantly affected different vegetative characteristics, such as plant height, number of leaves per plant, and plant dry weight, in the two growing seasons. Data indicated that using 2% aquagel-polymer gave the highest vegetative characters values followed by 1% aquagel-polymer during the two seasons, while the lowest values were taken by the control treatment (without gel-polymer).

The interaction between irrigation levels and aquagel-polymer treatments was significant for the studied vegetative characteristics during the two inves-

Table 2: Average Weekly Climatic Data during the two Growing Seasons

	1st season						2nd season					
Weeks	Max Temp	Min. Temp.	Ave. RH	Wind Speed	Solar Radi-ation	ETo	Max Temp	Min. Temp.	Ave. RH	Wind Speed	Solar Radia-tion	ETo
	°C	°C	%	m/s	[MJ/ m2]	mm/ Day	°C	°C	%	m/s	[MJ/m2]	mm/ Day
1	25,4	16,0	64,4	1,8	13,0	3,2	25,0	16,8	62,4	1,7	14,7	3,2
2	21,7	13,9	67,4	1,8	12,0	2,7	21,1	14,7	65,3	1,7	13,7	2,8
3	19,8	13,2	61,6	2,0	11,9	3,1	21,0	12,5	65,1	1,9	11,5	2,9
4	17,5	11,0	66,2	2,0	10,3	2,7	18,9	11,5	70,4	1,9	10,6	2,6
5	16,8	10,7	67,3	1,9	10,4	2,7	17,0	11,0	66,0	1,8	11,0	2,8
6	15,4	9,7	70,4	2,0	10,9	2,6	15,4	10,5	68,2	1,9	11,6	2,7
7	15,8	8,6	69,3	1,8	9,8	2,7	15,4	9,5	67,2	1,7	10,5	2,8
8	16,8	9,3	69,3	1,8	10,0	3,0	17,9	9,6	73,5	1,9	10,6	2,9
9	17,2	9,5	67,7	1,9	10,8	3,3	18,9	9,6	71,4	1,9	10,6	3,3
10	18,1	10,9	66,3	1,8	11,0	3,7	20,0	10,6	70,4	1,9	11,5	3,6
11	19,8	11,0	63,4	1,8	11,9	4,1	21,0	11,5	67,2	1,9	11,5	4,1
12	20,3	12,0	62,6	1,7	11,5	4,3	20,6	12,6	63,4	1,8	12,1	4,4
13	20,7	12,9	61,8	1,7	11,0	4,6	20,2	13,7	59,5	1,8	12,6	4,7
14	21,2	13,2	59,6	1,7	12,0	4,8	20,6	14,2	57,6	1,7	13,1	5,0
15	21,8	13,6	57,4	1,6	12,9	5,0	21,1	14,7	55,7	1,7	13,7	5,2

* Max Temp = Maximum air temperature.
* Min Temp = Minimum air temperature.
* Ave. RH = Average air relative humidity (%)
* Solar Radiation MJ/m2 = Solar Radiation (Mega joule per square meter)
* ETo mm/ Day = Evapotranspiration according to penman monteith equation which described in FAO 56 (Allen *et al*., 1998).

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Table 3: Average Irrigation Water Requirements during the two Growing Seasons for Celery

	1st season					2nd season				
Week No	ETo	Kc	ETc	+LR	Irrigation req.	ETo	Kc	ETc	+LR	Irrigation req.
	mm/ Day				L/ Plant/ Day	mm/Day				L/ Plant/ Day
1	3,2	0,6	1,9	2,3	0,4	3,2	0,6	1,9	2,3	0,4
2	2,7	0,7	1,8	2,1	0,4	2,8	0,7	1,8	2,2	0,4
3	3,1	0,7	2,2	2,6	0,5	2,9	0,7	2,0	2,4	0,4
4	2,9	0,8	2,3	2,7	0,5	2,6	0,8	2,1	2,5	0,4
5	2,7	0,9	2,5	3,0	0,5	2,8	0,9	2,5	3,0	0,5
6	2,6	1,0	2,5	2,9	0,5	2,7	1,0	2,6	3,1	0,6
7	2,7	1,0	2,7	3,2	0,6	2,8	1,0	2,8	3,3	0,6
8	3,0	1,1	3,1	3,8	0,7	2,9	1,1	3,1	3,7	0,7
9	3,3	1,1	3,5	4,1	0,7	3,3	1,1	3,4	4,1	0,7
10	3,7	1,1	3,9	4,7	0,8	3,6	1,1	3,8	4,6	0,8
11	4,1	1,1	4,3	5,2	0,9	4,1	1,1	4,3	5,1	0,9
12	4,2	1,0	4,2	5,1	0,9	4,3	1,0	4,3	5,1	0,9
13	4,4	1,0	4,4	5,3	0,9	4,5	1,0	4,5	5,4	1,0
14	4,6	1,0	4,4	5,2	0,9	4,8	1,0	4,6	5,5	1,0
15	4,8	0,8	3,8	4,6	0,8	5,2	0,8	4,2	5,0	0,9
Total					71,6	Total				72,2

* LR = Leaching requirements (assumed 20% of irrigation water).
* Kc = crop coefficient for celery during crop life.
* ETc = crop evapotranspiration for celery plants
* Irrigation req. = Irrigation water requirement for celery plants liter per plant per day

tigated growing seasons. The highest celery vegetative growth was produced by 100% irrigation level combined with 2% of aquagel-polymer, followed by 100% irrigation level combined with 1% gel-polymer. The celery fresh weight had the same trend of vegetative growth during both seasons. The highest irrigation level in the current study had the highest celery yield followed by 75% of IR. Using 2% aquagel-polymer gave the high-

Table 4: Effect of Soil Gel-polymer and Different Irrigation Water Levels on Vegetative Growth Parameters of Celery during 2015/2016 and 2016/2017 seasons

	First season 2015/2016				**Second season 2016/2017**			
	Number of leaves							
	Control	1% Aquagel	2% Aquagel	Mean	Control	1% Aquagel	2% Aquagel	Mean
100%	92.3 ab	89.6 b	92.0 ab	991.3 A	90.3 ab	87.6 b	95.0 a	991.0 A
75%	83.6 c	93.0 ab	97.6 a	91.4 A	81.6 c	91.0 ab	92.6 ab	88.4 A
50%	72.3 d	94.0 ab	80.3 c	82.2 B	71.3 d	92.0 ab	78.6 c	80.6 B
Mean	82.7 B	92.2 A	90.0 A		81.1 B	90.2 A	88.7 A	
	Plant height (cm)							
	Control	1% Aquagel	2% Aquagel	Mean	Control	1% Aquagel	2% Aquagel	Mean
100%	43.3 b	44.3 b	48.6 a	45.4 A	42.4 b	43.4 b	47.6 a	44.5 A
75%	35.6 c	37.0 c	42.0 b	38.2 B	34.9 c	36.2 c	41.1 b	37.4 B
50%	35.6 c	36.0 c	37.0 c	36.2 B	34.9 c	35.2 c	36.2 c	35.4 B
Mean	38.2 B	39.1 B	42.5 A		37.4 B	38.3 B	41.7 A	
	Yield (g)							
	Control	1% Aquagel	2% Aquagel	Mean	Control	1% Aquagel	2% Aquagel	Mean
100%	913 c	1018 b	1358 a	1096 A	894 c	997 b	1331 a	1074 A
75%	581 fg	762 d	937 c	760 B	569 fg	747 d	918 c	745 B
50%	563 g	651 ef	708 de	640 C	552 g	637 ef	694 de	628 C
Mean	685 C	810 B	1001 A		672 C	794 B	981 A	
	Dry weight (g)							
	Control	1% Aquagel	2% Aquagel	Mean	Control	1% Aquagel	2% Aquagel	Mean
100%	98.8 b	100.6 b	131.9 a	110.4 A	96.8 b	98.6 b	129.3 a	108.2 A
75%	77.6 de	89.2 bcd	93.1 bc	86.7 B	76.1 de	94.5 bc	99.6 b	90.1 B
50%	75.1 e	87.0 cd	90.5 bc	84.2 B	73.6 e	85.2 cd	90.7 bc	83.2 C
Mean	83.8 C	92.3 B	105.2 A		82.1 C	92.8 B	106.5 A	
	Base plant diameter							
	Control	1% Aquagel	2% Aquagel	Mean	Control	1% Aquagel	2% Aquagel	Mean
100%	4.5 c	5.0 b	5.5 a	5.0 A	4.4 c	4.9 b	5.4 a	4.9 A
75%	4.3 cd	4.3 cd	4.8 b	4.5 B	4.2 cd	4.2 cd	4.7 b	4.4 B
50%	4.0 e	4.2 de	4.5 c	4.2 C	3.9 e	4.1 de	4.4 c	4.1 C
Mean	4.3 C	4.5 B	4.9 A		4.3 C	4.5 B	4.9 A	

Means followed by the same letter within column or row are not significantly different (P<0.05)

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est celery yield followed by 1% of gel-polymer. These results agreed with findings by Abdrabbo *et al*. (2015), who tested the effect of different irrigation water levels (100, 75 or 50% of IR) for cabbage plants. The data illustrated that irrigation levels had insignificant effects on head weight and head quality, but the highest values were obtained by 100% irrigation levels. However, using aquagel-polymer could have utilized the nutrients more efficiently, thus, resulting in better plant growth (Petrova & Ovcharova, 2013). Plant growth and root growth in sandy substrate (control) can be improved by treating with polymer which imbibes water and, therefore, improves soil porosity (Klados & Tzortzakis, 2014). Plants grown on sandy culture with aquagel-polymer experienced less premature leaf senescence than the control (sandy soil). Furthermore, this indicated that good root growth leads to better plant growth and higher yields (Farag *et al*., 2015). The 100% ETo treatments applied in this study increased plant growth characters, namely plant height, number of leaves and total dry weight. The effect of 100% ETo irrigation level was statistically significant in both seasons compared to other irrigation levels (75% and 50% irrigation water).

Low irrigation levels could stunt plant growth as a result of reduced canopy growth and increased leaf thickness (Curtis and Claassen, 2005). On the other hand, the improved vegetative growth (i.e., plant height, number of leaves and dry weight) of celery plants at 100% of irrigation level may be due to enhance soil moisture and water availability, which created better conditions for nutrient uptake, better photosynthesis, and metabolite translocation (Nahar & Ullah, 2012; Saleh & Ozawa, 2006). Generally, it was clear that the best results for celery yield were obtained by the application of 100% irrigation level. These results might be due to adequate moisture content in the soil, which leads to more physiological processes, better plant nutrient uptake, and higher rates of photosynthesis. These results could be reflected by a higher number of fruits and fruit weight. Such findings are confirmed with those obtained by Olanike and Madramootoo (2014). Increased celery yield could be largely attributed to appropriate application of aquagel-polymer which resulted in enhancement of soil condition around roots of celery plants, increasing plant growth and, thus, nutrient uptake (abdrabbo *et al*., 2009).

Water use efficiently

Data in Table 5 shows the WUE for celery under different irrigation water levels and aquagel-polymer application with sandy soil. There were significant differences among different treatments during the two seasons.

Regarding the effect of different irrigation requirement treatments on WUE, data showed that there was a significant difference among treatments using 50% of IR followed by 100%; while, the lowest WUE was obtained by 75% of irrigation water. Data in Table 5 indicates that the highest WUE was obtained by 2% aquagel-polymer followed by 1% of gel-polymer, while the lowest WUE was obtained by control treatment. From the data, we can conclude that increasing irrigation water quantity above 50% of irrigation requirement can lead to a decrease in WUE. Similar results were obtained by Farag *et al*. (2015), who concluded that the addition of aquagel-polymer for growing media had enhanced WUE under different irrigation levels. Furthermore, El-Dolify *et al*. (2016) concluded that yield and WUE was highly affected by the applied amount of irrigation water and aquagel-polymer in sandy soil. Also, efficiency in water utilization has a marked influence in determining most of the physiological and agronomical performances observed in crop plants, especially vegetables (Abd-Elkader & Alkharpotly, 2016). Irrigation can be important for vegetable crops, such as celery, because many of these crops are shallow rooted and, therefore, sensitive to water shortage (Petrova & Ovcharova, 2013). As water supplies become scarcer and the cost of irrigation water increases, irrigation-scheduling methodologies need to be more precise by sustaining moisture supply with proper water quantity and aquagel-polymer, for example (El-Dolify *et al*., 2016). The irrigation water supplied, irrespective of irrigation method, is retained in the soil and efficiently distributed for crop growth (Klados & Tzortzakis, 2014). This enables the crop to significantly discern between the levels of irrigation received once the conditioner is added to the crop. Higher WUE is an integral part of conditioner as well as drip irrigation (El-Sayed *et al*., 2011).

Elemental content of celery leaf

Data in Table 6 shows the concentration of N, P and K in celery leaf cultivated in the sandy substrate under the tested treatments during the 2015/2016 and 2016/2017 seasons. Data revealed that the treatment of irrigation water at level 100% was adequate to give high celery leaf contents of N, P and K macronutrients. The experiment was carried out by using the drip irrigation system and high irrigation frequency based on climatic data. This means that a timer was used to organize irrigation time to deliver water quantity without excess water under all treatments. However, nutrient content of celery leaf was also improved by the application of soil conditioners to growing media due to the reduced impact of water stress during the growing cycle. This could be owing to the fact that sufficient water evidently has a positive effect on plant growth. It is well-known that water plays a vital

Table 5: Effect of Soil Gel-polymer and Different Irrigation Water Levels on WUE of Celery during 2015/2015 and 2016/2017 seasons

	First season 2015/2016				**Second season 2016/2017**			
	Control	1% Aquagel	2% Aquagel	Mean	Control	1% Aquagel	2% Aquagel	Mean
100%	12.7 f	14.2 e	18.9ab	**15.3 B**	12.4 f	13.8 e	18.4 ab	**14.9 B**
75%	10.8 g	14.2 e	17.4 c	**14.1C**	10.5 g	13.7 e	16.9 c	**13.7 C**
50%	15.7 d	18.2b	19.8 a	**17.9 A**	15.3 d	17.6 b	19.2 a	**17.4 A**
Mean	**13.1 C**	**15.52 B**	**18.7 A**		**12.7 C**	**15.1 B**	**18.2 A**	

Table 6: Effect of Soil Gel-polymer and Different Irrigation Water Levels on WUE of Celery during 2015/2015 and 2016/2017 seasons

	First season 2015/2016				**Second season 2016/2017**			
	N				**N**			
	Control	1% Aquagel	2% Aquagel	Mean	Control	1% Aquagel	2% Aquagel	Mean
100%	1.60 c	1.67 b	1.78 a	1.69 A	1.66 d	1.88 b	1.92 a	1.82 A
75%	1.55 c	1.62 c	1.71 b	1.63 B	1.47 f	1.78 c	1.76 c	1.67 B
50%	1.39 e	1.44 de	1.47 d	1.44 C	1.35 g	1.47 f	1.56 e	1.46 C
Mean	1.51 C	1.58 B	1.65 A		1.49 C	1.71 B	1.75 A	
	P				**P**			
	Control	1% Aquagel	2% Aquagel	Mean	Control	1% Aquagel	2% Aquagel	Mean
100%	0.32 cde	0.35 bc	0.39 a	0.35 A	0.34 bcd	0.38 b	0.40 a	0.37 A
75%	0.31 de	0.33 bcd	0.36 b	0.33 B	0.31 de	0.32 cde	0.37 bc	0.33 B
50%	0.27 f	0.29 ef	0.33 bcd	0.30 C	0.26 f	0.30 e	0.35 bc	0.30 C
Mean	0.30 C	0.32 B	0.36 A		0.30 C	0.33 B	0.37 A	
	K				**K**			
	Control	1% Aquagel	2% Aquagel	Mean	Control	1% Aquagel	2% Aquagel	Mean
100%	4.20 c	4.45 b	4.58 a	4.41 A	4.44 d	4.76 c	4.98 a	4.73 A
75%	4.02 d	4.20 c	4.38 b	4.20 B	4.14 f	4.30 e	4.59 b	4.35 B
50%	3.69 f	3.82 e	4.02 d	3.84 C	3.85 h	4.04 g	4.15 f	4.01 C
Mean	3.97 C	4.16 B	4.33 A		4.15 C	4.37 B	4.58 A	

Means followed by the same letter within column or row are not significantly different ($P<0.05$)

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role in all physiological processes of mineral absorption from the soil up to building different components inside the plant (Ekebafe, *et al*., 2011). These increases could occur for the reason that higher water availability enhances nutrient accessibility, which improves nitrogen and other macro- and micro-elements absorption as well as enhancing the production and translocation of the dry matter (Shahrokhian *et al*., 2013; Abedi-Koupai & Sohrab, 2004). These results were in line with those obtained by Farag *et al*. (2015) and Shahrokhian *et al*. (2013).

Regarding the using of gel-polymer, data in Table 6 indicates that using 2% aquagel-polymer led to an increase in NPK percentage of celery leaf. The increased nutrient content under gel-polymer application treatments could be largely attributed to proper soil properties due to application of the polymer. Such application resulted in an enhancement of soil condition around the plant roots zone, which also increased plant growth, and, thus, nutrient uptake (Maboko *et al*., 2006). Optimal root zone conditions allowed for adequate root function, including proper uptake of water and nutrients. Plant nutrient uptake, plant growth, and yield under mulch fit a quadratic relationship with root zone temperature. These results are in agreement with those obtained by Abedi-Koupai and Sohrab (2004). Similar results were reported by Abdrabbo *et al*. (2010), who mentioned that using optimum water quantity allow plants to use water and nutrients available from deep soil, thus, increasing water and nutrient use efficiency, and reducing nitrogen leaching.

Conclusion

Under sand substrate conditions, the physical properties can be improved by using aquagel-polymer by 2% volume. Thanks to its high water holding capacity, the aquagel-polymer reached 60 times per volume. Irrigation treatments conclude that due to adequate moisture content in the sand substrate, the celery yield was highest under application of 100% irrigation level than other irrigation levels (75% and 50%). Results suggest that aquagel-polymer at 2% compound with 100% Irrigation treatment at sand substrate enhance the celery vegetative growth yield. More research is needed to establish an application of aquagel-polymer in sandy soil under Egyptian conditions.

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Conflict of Interests

The author hereby declares that there are no conflicts of interests.

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Farmers might be able to vaccine their plants soon

Photo credit: Amber Shadow

Unlike animals, plants have no circulating immune system and their cells must respond independently. Plant cells can express special receptors to recognize pathogens and trigger various defense responses, including cell wall thickening, antimicrobial compounds, warning signals to other cells, and programmed cell death. The ability of the plant cells to recognize different pathogens is not acquired but preserved in their genes. A research group from University of Helsinki and the French National Centre for Scientific Research (CNRS) has developed an environmentally-friendly double-stranded RNA (dsRNA) vaccine that protect plants from pathogen

The produced vaccine activates the RNA interference (RNAi) mechanism, which is a biological defense method in eukaryotic organisms against pathogens. RNAi inhibits gene expression or translation for the gene of the targeted pathogen. The vaccine can be designed to target the gene of specific pathogens only without affecting the expression of the genes in the protected plants. The research team has demonstrated the efficacy of RNA-based vaccines produced using the new method against plant virus infections. This new method will enable the effective production of RNA-based vaccines and promote the development and adoption of RNA-based plant protection methods. The vaccines can be sprayed directly on the plant leaves and reduce the hazardous effects of the chemical pesticides to human health, beneficial organisms, and the environment.

Source

University of Helsinki. (2018, April 5). *A vaccine for edible plants? A new plant protection method on the horizon. ScienceDaily*. Retrieved April 14, 2018 from *www.sciencedaily.com/releases/2018/04/180405100141.htm*

Homemade food limits our exposure to phthalates

Photo credit SteFou

Phthalates are a group of chemicals that are widely used to increase flexibility, transparency, and durability of plastic. They are commonly found in food packages, takeaway boxes, gloves, food processing equipment, and other materials used to produce fast food meals. Many researches linked high levels of phthalates to a long list of serious health issues, including hormone disturbance, fertility problems, pregnancy complications, and birth defects.

A new study at the George Washington University, Washington, USA, found higher levels of phthalate in people who frequently consume shop-bought meals to those who consume homemade food. The research team used the cumulative phthalate exposure method, which is an innovative method to assess the real exposure to multiple phthalates, to collect and analyze the data from more than 10250 participants between 2005-2014. Significant association was underlined between phthalates exposure and consuming shop-bought food with higher magnitudes for teenagers. Phthalates levels were approximately 35% higher in the people who consume their meals in restaurants, fast-food shops, and cafeteria compared to the people who cook their own meals. Moreover, the consumed sandwiches at fast-food shops were associated with 30% higher phthalates levels in all ages. The study also revealed that adolescents, who consume or buy their food outside, had 55% higher levels of phthalates compared to those who consume food at home. Children, pregnant woman, and teenagers were reported to be more vulnerable to the phthalates' toxicity, thus future research should focus on finding the best practice to remove phthalates from the food supply. Furthermore, the phthalates problem should be addressed by politicians and policymakers to ban its usage and utilize other alternatives.

Source

George Washington University. (2018, March 29). Dining out associated with increased exposure to harmful chemicals: New study finds burgers and other foods consumed at restaurants, fast food outlets or cafeterias, associated with higher levels of phthalates. *ScienceDaily*. Retrieved April 14, 2018 from *www.sciencedaily.com/releases/2018/03/180329095722.htm*

Is the climate change interfering between the rare spider orchid and its special pollinators?

The right temperature and precise timing are essential for the relationship between the rare orchid and Buffish Ming-bee to be successful. Climate change is manipulating this relationship badly through the current rise in temperatures. A study being conducted at Sussex University is monitoring the rise in temperature since the mid-17th century, and its devastating impact on the relationship between the Buffish Mining-bees' pollination with spider orchid. Professor Hutchings, a Professor of Ecology and the research leader at Sussex University, revealed that spider orchid is endangered and can be explained by the increase in average temperatures. The new, accelerated temperature levels are affecting the orchid and other species, making them not able to respond effectively to the pollination mechanism. Thus, those species are declining and may face the threat of extinction. Moreover, he demonstrates that the climate change has a devastating impact not only on the spider orchid and Buffish Mining-bees, but it is also damaging interdependent relationships for many other species. Hutchings declares that this research is considered the best in documenting this effect of the induced climate change on specific species life cycles. But how is the climate change upsetting the vital interdependent relationships between spider orchid and Buffish Ming-bees?

Photo credit: IrartStudio

Pseudocopulation is the tricky mechanism that orchid deceives the male bees to undertake pollination. Spider orchid is fooling the males bees by releasing a scent that is similar the female bees' scent. This special smell fools the males and provokes them for mating. During pseudocopulation, the males catch pollen masses from the flower and transports them to other flowers during the next attempts for pseudocopulation.

The secret behind the success of pseudocopulation is that males must emerge first, then orchid must flower and tempt the males before the emergence of the female bees. Unfortunately, high temperatures have manipulated this natural sequence of events that are needed for a successful pollination. This rise in temperatures has been noticed since the early mid-seventeenth century. A 1 °C rise in temperature during spring has caused the three important sequence of events (male emergence, orchid flowering and female) to occur earlier by 9.2, 6.4 and 15.6 days, respectively. Thus, and due to the fact that the intervals between the emergence of males and females has reduced significantly, the females are now reaching peak flying before orchid flowering by more than one week. Between 1659 and

1710, the peak flying of the female bees occurred 40% more often before the orchid flowering peak. However, this percentage has raised to 80% between 1961 to 2014. As a result, male bees are mating with the female bees rather than pseudocopulas with orchid, simply due to the fact that natural mating can be done with the already-emerged females. Therefore, orchid pollination is failing almost every year, or it is happening only when temperatures are low.

Since 1930, 60% of the orchids have declined in UK due to the climate change and other factors, such as intensive graze and inefficient pollination. Professor Hutchings is dragging attention to the fact that unless the orchid starts to flower earlier, it is likely that flowering will continue to occur always after the female bees emerge. Thus, the pseudocopulation will then never happen and the rare spider orchid will become extinct. However, a hand pollination program may be the best and only solution to ensure that the spider orchid remains.

Source

University of Sussex. (2018, April 6). Climate change is wreaking havoc on delicate relationship between orchids and bees: The first definitive demonstration of climate change upsetting the vital interdependent relationships between species has been revealed. *ScienceDaily*. Retrieved April 13, 2018 from *www.sciencedaily.com/releases/2018/04/180406085510.htm*

Prof. Tengiz (Gizo) Urushadze awarded with the honorary membership of the International Society of Soils

Photo credit: soil.ge

The 21st World Congress of Soil Science took place in Rio de Janeiro, Brazil, on the 16th of August 2018. During the Gala Dinner on Thursday, August 16th, the Award Ceremony was held in which the IUSS award winners 2018 and the new IUSS Honorary members were acknowledged. Academician Tengiz (Gizo) Urushadze, Professor of the Agricultural University of Georgia and Director of Michail Sabashvili Institute of Soil Science, Agrochemistry and Melioration, was selected as an Honorary Member of the International Union of Soil Scientists – a unprecedented case in the history of Georgian Soil Science. The congress was attended by more than 7000 delegates from 145 countries from all over the world. The honor of being a selected honorary member was awarded to only 92 scientists since 1924.

Report

The World Organic Forum 2018 at Schloss Kirchberg

Reported by Diana Ismael

Photo credit: Schloss Kirchberg

The World Organic Forum took place for the second year at Schloss Kirchberg, Haus der Bauern, from the 7th – 9th of March 2018. The international congress was organized by the "House of Farmers" foundation with other partners believing that the world needs a turnaround in agriculture. The conference provided space for discussions about the development of more efficient alternatives to the general capitalist business model in order to maximize profits. This year, the focus was on the future of agriculture and food in our world, the rights of small farmers, and solidarity economies.

Green Revolution representatives strongly believe that the world can be fed only with high-yielding varieties (HYVs) and with the help of lot of chemicals, modern agriculture, and efficient structures. Although those methods may give the desired results, the price is, and will be, very high: Biodiversity is decreasing, modern agriculture offers less and less chances for employment, and small farmers cannot survive, in addition to the negative effects on the quality of soils, groundwater and air. Thus, the world is in urgent need for a turnaround in agriculture that focuses on the environment, saves the natural resources, and encourages family farming, without compromising the adequate nutrition of humans. The conference focused on organic farming and the preservation of smallholder farming by strengthening their rights. This is the vision and the "New Age of Enlightenment".

The congress started on the 7th of March with a welcome speech and introduction by Rudolf Bühler, the Chairman of the House of Farmers Foundation, and Founder and Chairman of the Farmers Association. Then, Dr. Alexander Müller, a former General Secretary at FAO and the Sustainability Council of the Federal Government, gave the keynote speech on the "External Cost of Modern Agriculture to the Agrobiodiversity".

Over the course of the next two days, the conference consisted of three main blocks and one final block of working groups and discussions. The blocks were called: "The Future of Food and Agriculture in the World", "To Feed the World 'Organic' or Not at All", and "Global Peasant Rights". Michael Windfuhr, Deutsches Institut für Menschenrechte, gave a speech on UN human rights declarations named "Can a Declaration of the UN Human Rights Council Make a Difference?". The congress then closed its sessions with a working group session and a final discussion. In conclusion, the World Organic Forum was beneficial and gave the right platform for scientists, experts, farmers, and even students, to discuss in general the need for a change in the agricultural paradigm.

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1st SUSPLUS Project, Innovative Education Towards Sustainable Food Systems

Reported by Diana Ismael

Photo credit: Susplus

SUSPLUS project is a cooperation between eight European universities, Warsaw University of Life Sciences (Coordinator), University of Kassel, University of Copenhagen, Estonian University of Life Sciences, Münster University of Applied Sciences, ISARA-Lyon, University of Gastronomic Sciences, Bra and Universidad Politecnica de Madrid. The project was launched in 2016 and will continue until December 2018.

The project aims at developing and implementing innovative educational methods that support the concept of sustainable food systems, including innovative E-learning, intensive summer school, small research projects and lectures of students at schools. The project's aims are based on the important connection between today's unsustainable food systems and the current global challenges, both of which are threatening our natural resources, the environment, and overall human health.

SUPLUS project had its 1st International Conference during BIOFACH – the world's leading trade fair for organic food on February 2018 in Nuremberg (Germany). Various actors attended the conference, including food industry stakeholders, students, and representatives of higher education institutions. The conference focused on the definitions of Sustainable food systems, how students understand the concept of sustainability, and discussed future expectations towards the current educational system regarding this subject area.

In addition, the speakers discussed innovative approaches in education for sustainable development with an emphasis on organic systems and presented the results of a multi-country survey on student understanding of sustainable food systems, as well as reports on e-learning and summer school. Moreover, some of the students who participated in SUSPLUS educational activities, such as E-learning and summer school, were invited to participate in the conference and share their experience with international experts. At the end of the conference, the partners signified the guide/booklet on sustainable food system concepts as one of the key project outcomes, and an open discussion was held to share experiences, answer questions about the project, and exchange knowledge.

Future of Food: Journal on Food, Agriculture and Society, 6 (1)

ERPI 2018 Conference: "Authoritarian Populism and the Rural World", International Institute for Social Studies (ISS), The Hague, 17-18 March 2018

Reported by Sören Köpke

Photo credit : Salena Tramel from steps-centre.org

"It's hard to start on an uplifting note", that is how Murat Arsel of the International Institute for Social Studies (ISS) began his introductory speech to the conference. And indeed, the political perspective for many looks terrible: Authoritarian leaders and populist demagogues are eroding democracy in many countries all over the world, from India to Hungary, from Poland to the Philippines, and from Turkey to the USA. Since the conference, sadly, Italy has become the newest addition to the list. Chauvinistic nationalism, racism, homophobia, misogyny – these are the ideological components of a right-wing populism that is surging in many countries.

The conference "Authoritarian Populism and the Rural World" was an attempt to address these worrisome, if not enraging, political tendencies. The organizers have decided to link authoritarian populism to the multiple struggles and upheavals that concern rural people and the agrarian question. Why is it that authoritarian populist politics gather so much support in the countryside? How does it connect to the political economy of neoliberal globalization? Where are pockets of resistance, such as grass root networks organizing against the far-right?

More than 250 people from 60 countries – two fifths of them activists from NGOs, the rest academics – thought that the topic was important and came to the Dutch capital. The rooms of the ISS provided a welcoming space for exchange and debate. Furthermore, debate was a central aspect of this meeting, and the power point origins typical for academic conferences were replaced by lively discussion. The idea of the organizers was to distribute conference papers beforehand, so that every participant would have the chance to read and comment on a bunch of articles from her or his own working group. This format proved to be relatively successful, although it was a bit unusual and left me, at least, a bit confused.

Through its high-profile organizing committee, the conference managed to attract some of the "big names" in critical agrarian studies, with pundits like Ruth Hall, Marc Edelman, Ian Scoones, and Saturnino "Jun" Borras. Among the panelists were Indian intellectual Achin Vanaik, who presented his new book on the "Rise of Hindu Authoritarianism"; Zack Exley, who has organized for the Bernie Sanders campaign in the US; Raj Patel, who just released his book "The History of the World in 7 Cheap Things", written together with Jason Moore; and more activists, artists, and scholars from countries like Turkey, Myanmar, Ghana or Indonesia.

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An obstacle to a straightforward conversation was soon discovered in the different theoretical and political outlooks. What do we mean when we talk about "Authoritarian Populism" (in the following: AP)? Stuart Hall coined the term in the 1980s, originally as a theoretical framework to understand Thatcherism in the UK. Why not talk of "fascism" instead, given the violent nature of many right-wing movements? Is it adequate to use AP as a term in context of the far periphery of the world economy, such as in Zimbabwe? Why spend so much time discussing words and concepts, instead of actual political processes?

Many of the stories we heard over the two days were not exactly heartening. Progressive people who care about issues like human rights, labor struggles, environmental justice, and resilient local communities, are on the retreat in many countries. Yet, there was no air of frustration in these rooms. On the contrary, it was great to meet so many people who cared about just transformation and saw the rural world as a crucial starting point to these changes. The numerous encounters with people inside and outside academia, from developed and developing countries, were truly enriching. Certainly, right-wing populism will not suddenly vanish. But there seems to be many scholar-activists internationally who are critical, courageous, and ready to form new alliances. I hope the debate on meaningful alternatives to the right-wing turn will continue far beyond the conference and inspire many people.

University Award for Excellence in Teaching

Reported by Diana Ismael

"Change will not come if we wait for some other person or some other time. We are the ones we've been waiting for. We are the change that we seek." - Barack Obama

Under the frame of the teaching project "Students plan for students", Boris Rhein, the Hessian Minister of Science, awarded the Hessian University Award for Excellence in Teaching 2018 to seven students from Kassel University, Faculty of Organic Agricultural Sciences: Olga Olashyn, Foruq Zahra Kanaani Kotamjani, Isabel Greenberg, Bianca Gonçalves da Costa, Hichem Fourati, Diana Ismael, and Rami Al Sidawi.

The University Award for Excellence in Teaching Prize is dedicated to honor the outstanding teaching and learning methods that was initiated by students for the benefits of the students. The prize ceremony took place at the Senckenberg Biodiversity and Climate Research Centre (BIK-F), Frankfurt on 17 May 2018. A prize of 10,000 Euros was awarded to a special students' initiative: International Lecture Series (Ringvorlesung) inspired by Module UN at Kassel University.

The English-language Lecture Series (Ringvorlesung) "Climate Change, Migration and Violent Extremism: The United Nations' Role in Preventing Conflicts Spurs by The Challenges of Our Time" aimed at drawing the students' attention to current global topics, such as hunger, climate change, migration, and resource scarcity. The Lecture Series started in 2016 and will continue to take place at Kassel University in 2019.

Photo credit : wissenschaft.hessen.de

Picture 1: (Left to Right) Jury member Prof. Dr. Petra Gromann, Olga Olashyn, Foruq Zahra Kanaani Kotamjani, Isabel Greenberg, Bianca Gonçalves da Costa, Hichem Fourati, Rami Al Sidawi, Diana Ismael and Boris Rhein (Minister of the Education and Science)

The participants are able to engage not only by listening to the lectures, but also by actively participating in the discussions. Moreover, during the lecture series, participants can join in the drafting process of the "Witzenhausen UN Charter" that will be officially presented to the UN Secretary General. International and national speakers, local experts, activists, and practitioners from all over the world were invited to give a speech personally or via video conference in the lecture series, which created an international exchange of knowledge. "With the award of the Hessian University Award for excellence in teaching, we have taken on a pioneering role nationwide. The award highlights the outstanding importance of teaching for the education of young academics. In addition, it creates an incentive to engage in higher education", said Minister of the Education and Science, Boris Rhein.

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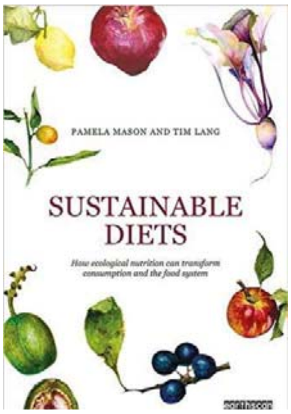

Sustainable diets: How ecological nutrition can transform consumption and the food system

A review by Jessica Lucinda Amprako

Author: Pamela Mason and Tim Lang
Publisher: Taylor and Francis Group
Published year: 2017
ISBN: 978-1-315-80293-0
Length: 343 pages

In a world where food consumption and its production seem to threaten the environment in diverse ways, access to affordable, culturally acceptable and nutritious food remains a challenge. According to Garnett (2014), food consumption contributes to 20-30% of anthropogenic greenhouse gas emissions and accounts for 70% of human water use and a source of water pollution. Urbanization, social status, culture and lifestyle changes have contributively altered consumer behaviour of todays' generation. It is against this background that the current food system needs to be re-evaluated.

The complexity of the current food system makes it extremely susceptible to climatic, socio-economic, political and financial crisis. The movement towards a more sustainable diet, with low inputs and the adoption of local and agro-ecological food production, coupled with shorter distance production-consumption nets for fair trade seems to be an effective alternative. Similarly, this review aims at discussing the different perceptions held on sustainable diets and posits on how ecological nutrition can transform food consumption and the food system.

Although sustainable diet is the way forward, it is not easy to assess. According to Perignon et al. (2016), high-quality indicators are needed to assess the social, economic and environmental dimensions of a sustainable diet. For instance, if environmental impacts of diets are limited to energy and micronutrient content of the diet or using basic nutritional indicators, a clear conclusion of sustainability results cannot be achieved. Consequently, the authors of this book have proposed a sustainable dietary guideline strategy. They evaluate the impact of diet on environment, health, social values, quality, economy and governance. This provides a deeper understanding of a 'good' and 'sustainable' diet (Mason & Lang, 2017).

These authors with a rich background in food policy, public health, and nutrition have addressed the omissions and gaps in the literature and challenges overall to transform food consumption towards sustainability. Pamela Mason, one of the main authors of this book under review, has a bachelor's degree in pharmacy, as well as a MSc and PhD in Nutrition from King's College in London, United Kingdom (UK). She also has a MSc in food policy from City University of London, United Kingdom. Pamela is a registered public health nutritionist with the UK Association for Nutrition. She is working with local food networks in Monmouth, South Wales.

The second author, Tim Lang, is a Professor of food policy at the Centre for Food Policy at City University of London, UK. Lang also co-authored this book. He was the founder of the Centre for Food Policy since 1994 and was Director until 2016. He authored a book on Food Wars and the Unmanageable Consumer in 2015. Other books authored by him include the Ecological Public Health (2012) and Food Policy (2009). He was the policy co-lead on the EAT-Lancet Commission on Healthy Diets from Sustainable Food Systems since 2016 to 2017.

Indeed, the present food production, supply, and consumption system cannot satisfy the growing population. Although the food system generates food energy for over 7 billion of the world's population, adequate and affordable nutrition is lagging (Garnett, 2014). Our food system is deficient in micronutrients and promotes obesity due to the excess intakes of fat and sugar. New strategies need to be developed to ensure food security and quality. Without any actions, these problems will gradually become acute. But the question remains unanswered. Will new strategies and mass production solve the problem of unsustainability in our food diet?

Sustainable diet refers to a diet that is environmentally friendly and contributes to food security and nutrition of all generations. According to Mason and Lang (2017), a sustainable diet also adheres to dietary guidelines for maintaining long-term health and avoids excessive degradation and consumption of natural resources. This includes a diversified diet which is high in quality, nutritious, and safe. Moreover, a sustainable diet aims at protecting biodiversity, while simultaneously meeting the socio-economic and cultural goals of humans.

Although the concept of nutrition and incorporating sustainability in the human diet is nothing new, it is one of the main topics in the current world of food policy due to the impact it has on the environment (Meybeck et al., 2015). However, achieving a sustainable diet is saddled with many controversies from a social, economic and environmental perspective. Arguably, a sustainable diet is often limited to being environmentally sound or healthy, but the economic and social aspects remain silent.

According to Burlingame and Dernini (2012), 70% of the world's population in 2050 will be urban dwellers. Changes in society, as a result of rural migration and a growth in income, lead to the consumption of more animal products, and an increased demand for livestock feed that is putting pressure on natural resources. A change in dietary patterns will require a drastic shift from the production side to healthy, low environmental impact food. In this light, Mason and Lang (2017) capture certain hidden factors, such as culture, social values, price of food, and cost of production, among other factors.

Undoubtedly, the world is seen to undergo a transition in nutrition. Food items, which were once seasonally available, can be purchased annually. The evolution of large-scale retailers has introduced changes in consumer food choice behavior (Meybeck et al., 2015). Consumers, with their lifestyle and food choices, play a leading role in the food production system as they select certain types of products, production processes or producers. Increases in income has led many to eat 'feast-day' meals each day. As our population grows and the economies of different countries improve with industrialization, the demand for more resources and energy rich foods, such as animal products, are on the rise (Garnett, 2014).

Population growth, as stated by Meybeck et al. (2015), is accompanied by an increase in the number of people that can increase their income. As high incomes are earned, more food is consumed. The probability of consuming certain foods, which were once impossible due to financial status, now become a common habit. Simpler food diets have given way to complex diets. This implies that traditional diets are gradually replaced by diets high in calories, refined sugars, meat and fats. Unfortunately, this direction embarked is responsible for global obesity and an incidence of non-communicable diseases does not emphasize who pays for the true cost of food (Meybeck et al., 2015).

It is obvious that price is one of the determinants of food consumption choices. In contrast, low food prices reduce investment capacity and affects economic sustainability. Promotion of low production costs not only encourages negative social impacts like low income and wages for food producers and workers, but encourages other negative environmental practices like food waste (Meybeck & Gitz, 2017). If the pursuit of cheaper food continues to shape the world food systems, it is the environment that pays in the end. The cost of food should be assessed based on the effects of sustainability, considering different approaches to production and food consumption.

More often, sustainable diets are limited to impacts on the environment or economy. However, the element of social aspects is often ignored. Mason and Lang (2017), emphasize on this gap in the literature by defining a sustainable diet as one which is socially just and safeguards the health and safety of workers by providing decent working conditions. The social conditions shape eating patterns. It highlights the social values pertaining to food diets, and the role social morals and cultural norms play in what one consumes.

Some social movements, such as for fair trade, animal welfare, and workers' rights are also trying to redefine the 'social' element in diet. They try to address the importance of the welfare of workers, farmers, and farm animals in a sustainable system. For example, proponents of animal stress on less meat production to prevent the continuous pain suffered by farm animals before slaughter. Additionally, workers' rights need to be protected. Thus, farmers and farm workers need a decent living and equal access to farm land. However, this issue is entangled with some cultural debates. Thus, the cultural aspects of food diet are worth noting.

Although a good diet may satisfy human and environmental health, if it is not available to everyone in a form that is culturally appropriate, it cannot be classified as sustainable. Therefore, the movement towards sustainable diets should consider the socio-cultural factors behind eating patterns. In some instances, food also provides social pleasure and

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identity. Critics seeking more sustainable diets have sometimes appealed to tradition and historic authenticity as a motive for change. A chapter in this book is dedicated to identifying and clarifying the social and cultural dimension of sustainable diets, drawing knowledge from some social movements.

Furthermore, as most of the focus on sustainable diet is centered on the socio-economic and environmental implications, good governance and policy is needed to shape consumer behavior. Some proponents of sustainability postulates that a sustainable dietary guideline as one of the ways forward. With a sustainable dietary guideline, a systematic approach can be followed by all to arrive at a uniform method of sustainable consumption. In addition to an effective guideline, an effective policy is essential to shape the food system for the future.

If consumers are to act as food citizens, they need some form of cultural rules. These rules or policies need to be transparent and open to audits. More so, a framework of governance needs to be designed to direct discussions leading to effective results. A transition team in this process of policy implementation will be useful to spearhead the shift, provide reasons for choosing a more sustainable diet, and direct its implementation. However, good governance is saddled with problems, such as good leadership, and legitimacy which this book addresses.

In addition to the existence of an effective framework towards sustainability in diets, it is essential for policy makers, food companies, scientists, and consumers to have an indicator for measuring sustainable diets. Increasingly in other chapters of this book, various guidelines towards a sustainable dietary is drawn from government, business and civil society. It introduces various indicators that both policy makers and the public adopt to measure sustainable diets. Indirectly, the reader is provoked to answer questions, such as when, why and how the (un) sustainability of diets can be measured. In this view, one can assess the reliability of a chosen indicator.

Briefly outlined, sustainable diets in this context is being assessed by public health indicators, such as obesity and incidence of Non-Communicable Disease (NCD), safety indicators (pathogens, antibiotics and pesticides), nutrition indicators (intake of energy, macronutrients and micronutrients), healthy eating and quality indicators, as well as other indicators in relation to diet like environmental, economic, and food security measures. Besides these indicators, a working guideline is needed to develop a standardized multi-criteria methodology for assessing sustainable diets.
The effectiveness of the concept of a sustainable diet is grounded on the idea that to increase sustainability of systems, both production and consumption, and supply and demand, need to be considered. The choice of diet and food consumption affects sustainability. There are increasing opportunities for more sustainable consumption patterns and choices to drive towards greater sustainable production patterns. A comprehensive view of the contributions made on this topic in this book gives an informed direction towards sustainable diets. However, sustainable diets are both constrained and enabled by the food system. Therefore, the state of the food system determines the space of possible diets and the possibility to choose sustainable diets based on the number of consumption choices and incentives available.

The core concept of such a movement is not limited to public health. It must consider the socio-cultural aspects of the consumers, economic issues from farm to fork, and the environmental effects of the choice of diet.

Overall, the food system is shaped by many drivers, its status being the result of different diets, environmental, economic and social issues at different levels from local to global. Therefore, a general guideline for sustainable diet can be downplayed by most sustainability proponents. This is because many economies and consumption choices are bound to evolve. Thus, food diet and eating patterns are often influenced, if not controlled, by culture, beliefs, status and place.

Information about the author:

Jessica Lucinda Amprako is a doctoral candidate at the University of Kassel, Germany.

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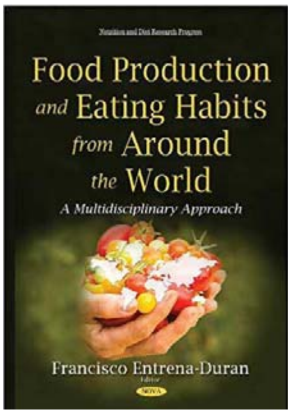

Food production and eating habits from around the world: A multidisciplinary approach

A review by Karla Lorena Andrade Rubio

Editor: E. Francisco
Publisher: Nova Science Publishers
Published year: 2017
ISBN: 978-1634824965
Length: 248 pages

The reader has before him/her a comprehensive interdisciplinary book of universal research that is being globally disseminated. The problems and mutations in eating habits discussed in this volume are contextualized by the editor within the current scenario of globalization. In this scenario, several food consumption patterns are affected by the glocalization phenomenon, which indicates both the localization of the global and the globalization of the local (Robertson, 1995; Roudometof, 2016). This entails that at the same time that processes of homogenization of food behaviors occur on a planetary scale, numerous local foods and types of cuisine are globally adopted by many individuals (Bain, 2013; Hall & Gössling, 2013).

The five parts of this book were written by experts in different disciplines, such as Anthropology, Psychology, Economics, Nursing, Communication, Marketing, Medicine and Sociology. Thus, the chapters do not have one single theoretical-analytical framework, although it must be said that all of them are fine and clearly written, and well-grounded from a theoretical and methodological perspective.

The first part of the volume, titled "Food Production" begins with Chapter 1: "Deagrarianization, the Growth of the Food Industry, and the Construction of New Ruralities", in which Francisco Entrena-Duran shows that many present-day rural societies are undergoing trends to deagrarianization, which occurs hand in hand with the increasing industrialization of food production processes. Thus, the food process and food consumption become ever more away from agriculture and livestock.

Chapters 2 and 3: "Expansion of Greenhouse Farming in the El Ejido Area: A Case Study on the Environmental and Social Consequences of Agroindustry in Southeast Spain" and "Effects of Pesticides on Cambodian Farming and Food Production: Alternatives to Regulatory Policies", written respectively by Entrena-Duran and Ramos-Sanchez, deal with the socioeconomic and environmental outcomes and the ecological effects brought about by the agro-industrialization of food production in Cambodia, respectively.

The second part examines "Eating Habits, Physical Activity, Body and Health". This section begins with a chapter called "The Impact of Physical Activity and Psychological Factors on Eating Habits," authored by Mawusi-Amos, Dzifa-Intiful, Antwi, and Asante. The chapter explores the main psychological impacts that shape eating habits. Moreover, it emphasizes the importance of physical activity for individual health.

In Chapter 5: Strategies for the Care of the Obese: A Non-Prescriptive Nutritional Perspective, Dimitrov-Ulian *et al*. (2017) reveal that concerns over obesity are reflected in multiple actions aimed at controlling body weight, such as prescriptive interventions, that are diet-focused and consider weight loss as their primary indicator of success. However, despite these actions, the prevalence of obesity is considerably high and rising. As alternatives, the authors propose a series of strategies that are less focused on the prescription of strict diets and more on personal autonomy. Nutritional counseling and the reinforcement of positive eating habits constitute the keystones of the aforementioned strategies.
Then, in Chapter 6: "Body Cult in Contemporary Societies: Sport, Self-Image and Health", Valdera-Gil and Valdera-Gil deal with, among other things, the diversification of sport practices and the tension between the commodification of the body aesthetic patterns and the real circumstance in

which habitually there are a large number of obese people. Subsequently, in Chapter 7: "Eating Habits: Falls and Stroke Risk", Kamberi, and Kamberi show us how, in the Republic of Macedonia, Christians often consume pork, while Muslims do not. Nonetheless, medical empirical research, on which these authors are based, does not demonstrate the existence of a clear link between this cultural eating habit and the first attack of ischemic stroke. Consequently, the authors assert that such stroke could be due to other numerous risk factors.

The third part, "Advertising and Discourses on Food", begins with Chapter 8: "Between Health and Beauty: Food Advertised as Medication". The author, Rey, states that the obsession with attaining that beautiful body image promoted by the media, which is so rooted in advanced societies, cannot be understood as an isolated phenomenon. Instead, it needs to be contextualized within a larger background to be explained as the consequence of a complex process shaped by the cult of the body and the medicalization of food.

Next, in Chapter 9: "Health as a Hook in Food Advertising", co-authors Gonzalez-Diaz and Iglesias-Garcia illustrate a connection between marketing and everyday health concerns on television advertisements about yogurts, perishable desserts, and diverse lactic products. They assert that in the present-day framework of increasing social concern for health, transnational food companies are marketing a series of commodities, namely functional foods, which are sold as being healthy for consumers.

Later, in Chapter 10: "Food, Marketing and Culture: Discourses of Food Advertising in Spain", Gracia-Arnaiz states that Spanish food advertising is articulated by the combination of six key discourses. These are the discourses of tradition-nature-identity, the medical-nutritional, the aesthetic, the hedonist, that of the progress-modernity and that of social differentiation.

The fourth part, "Children's Eating Habits," starts with Chapter 11 on "Identifying Eating Habits in Multicultural Schools through Focus Groups with Children". Throughout the text, Merino-Godoy and Palacios-Galvez present the results of a research carried out in multicultural schools located in the southern Spanish region of Andalusia. The research was focused on Early Education (three to five years) and the First Cycle Primary (six to eight years) of school children. Among other findings, the authors conclude that these students lack basic awareness of diet and nutrition, yet they can perfectly reproduce the jingles and slogans of food products advertised on television.

Anibaldi, Rundle-Thiele, Crespo-Casado, and Carins collaborate on Chapter 12 titled "Insights into Children's Lunchboxes: Understanding the Issues Impacting the Selection of Contents by Australian Parents". The research reveals that although parents are generally well-informed and well-intentioned with respect to their children's food consumption at school, the contents of many lunchboxes are not nutritionally balanced with the inclusion of 'extras' being particularly worrisome.

The latter part of the volume is devoted to "Changes in Eating Habits" and contains two chapters. In Chapter 13: "Changing Urban Food Consumption Patterns in the Context of Globalization: The Case of India", Vepa and David assert that Indian urban people have never produced and consumed a higher amount of vegetables, fruits, milk or eggs. The diet has diversified considerably, but the average consumption of proteins has diminished. At the same time, the intake of fats has grown, particularly for people with lower incomes.

Lastly, in Chapter 14, Entrena-Duran and Jimenez-Diaz write on "Social Changes and Transformations in Eating Habits". They view eating habits as social constructions of human beings. This means that similarly to what happens with any other human construction, eating habits are subject to social change. The transformations that eating habits are currently undergoing are a result of the social changes brought about by globalization processes in advanced countries.Given its multidisciplinary nature and the wide variety of issues it addresses, the book reviewed here can be worthwhile and appealing for a broader audience.

Information about the author:

Karla Lorena Andrade Rubio is a Professor of Sociology at the Department of Social Work at Tamaulipas University (Mexico), and is a member of the National System of Researchers of Mexico (SNI 2).

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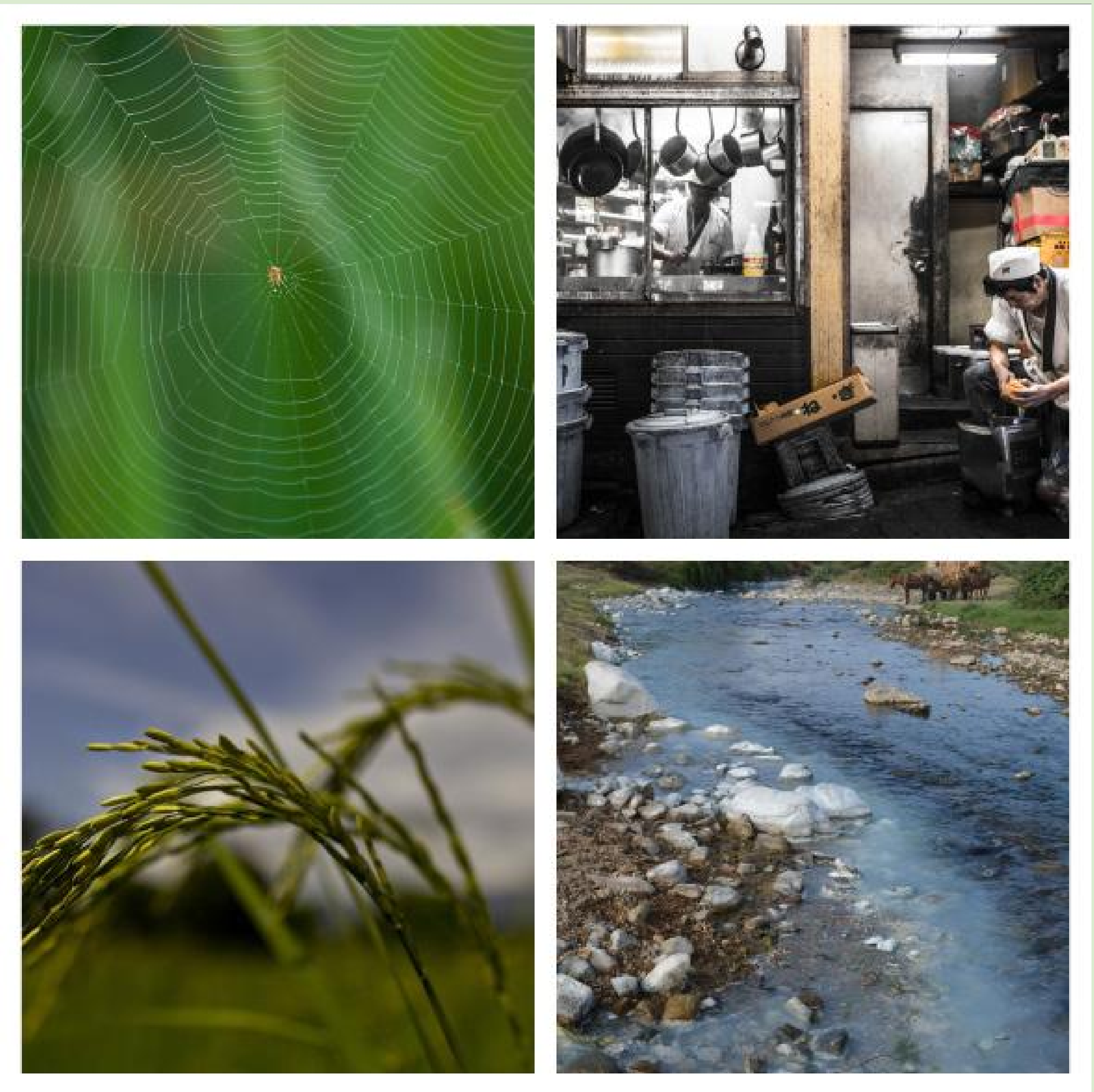

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Faculty of Organic Agricultural Sciences, at the University of Kassel, Germany
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